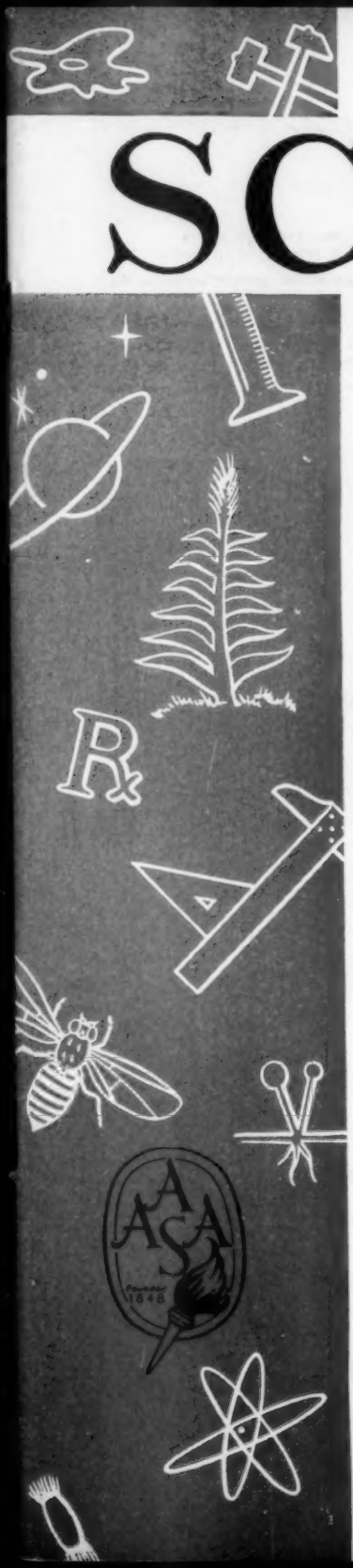

SCIENCE

22 OCTOBER 1954

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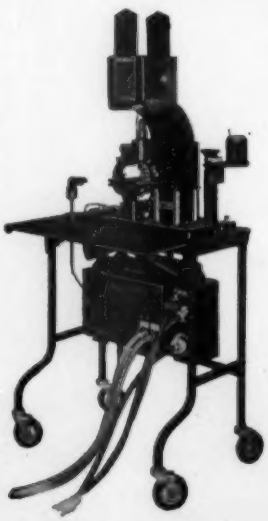

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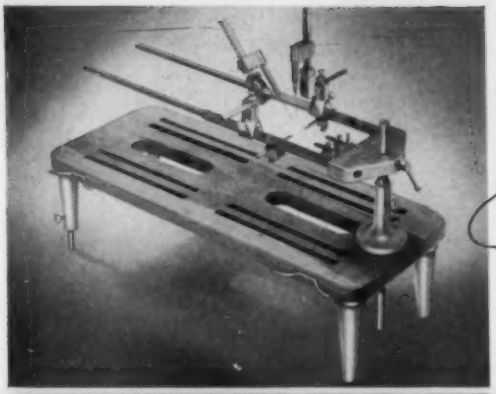

TOP: *Stereotaxic Instrument mounted on adjustable hardwood stand No. G-109, and showing one application of extension bars with 2 electrode carriers. Rigidity of instrument is an important feature for precision work.*

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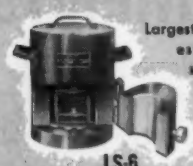

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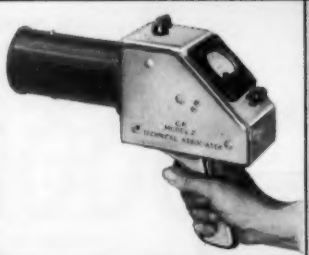

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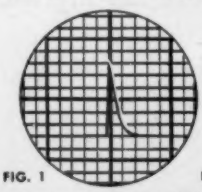

FIG. 1

FIG. 2

The pulse, viewed on a cathode ray oscilloscope, is of spike or saw-tooth shape, with a practically instantaneous rising phase, and an exponential falling phase. The instrument will produce a single isolated pulse (Fig. 1), which may be repeated at will, or a train of pulses of predetermined rate (Fig. 2).

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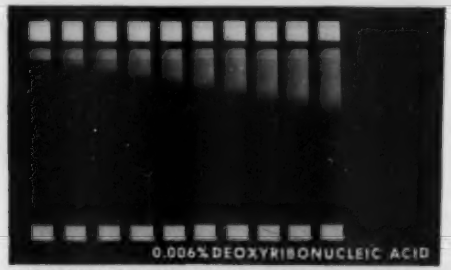

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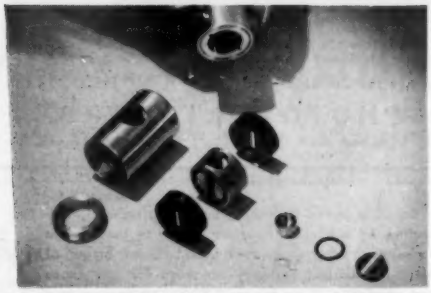

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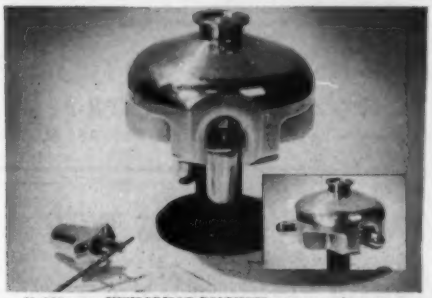

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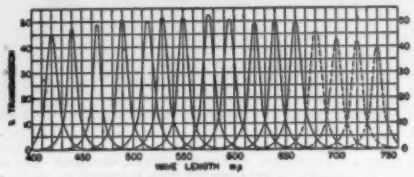

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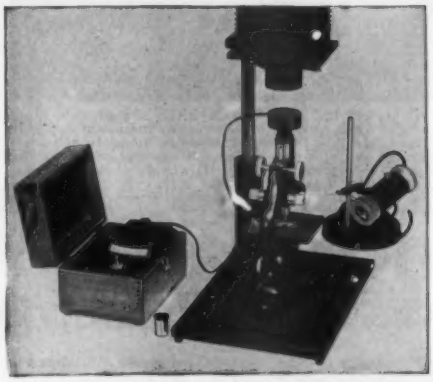

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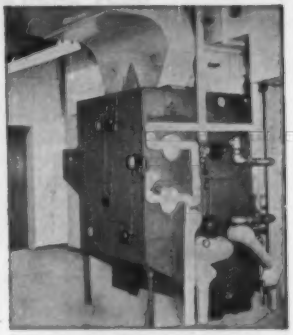

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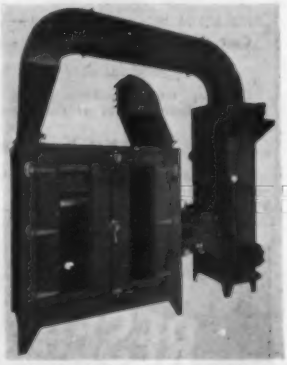

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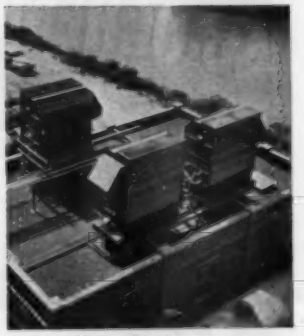

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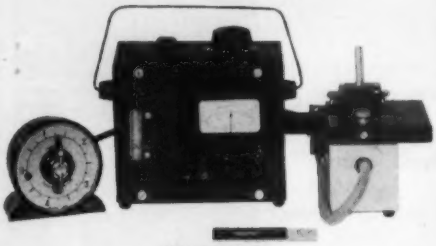

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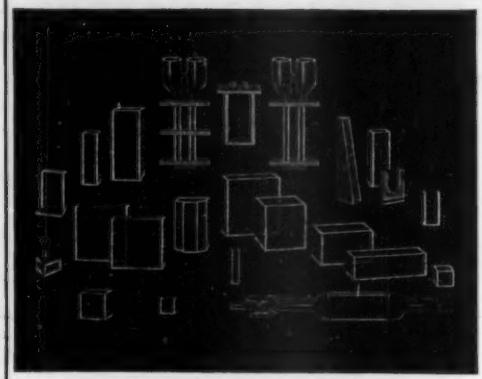

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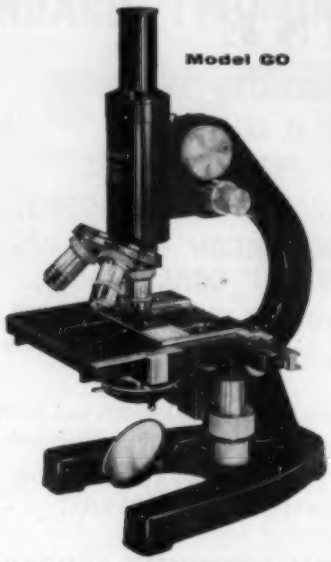

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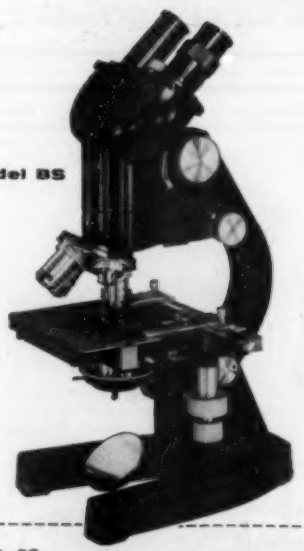

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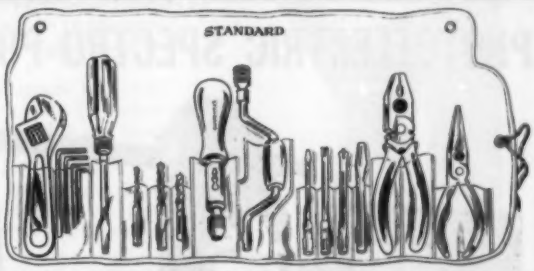

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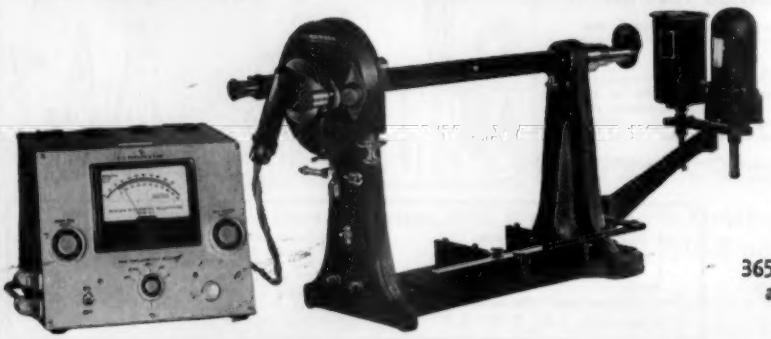

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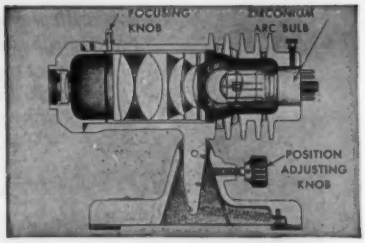

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Instrumentation—Revolution in Industry, Science, and Warfare

DURING the last century, man's muscular burdens have been partly transferred to machines. Now, instruments are at hand for automatic supervision and control of these machines and manufacturing processes. The vigorous growth of this field of instrumentation is accelerating revolutionary changes in industry, science, and warfare. The extent to which these developments have progressed was impressively shown at the First International Instrument Congress and Exposition held by the Instrument Society of America in Philadelphia last month (reported elsewhere in this issue).

Notable among the exhibits were the increasing number of devices for automatically representing the results of measurement in numerical form or as recorded signals in code (as on magnetic tape) for further use in automatic computation or control. The handling of measurement information in numerical (digital) form permits a considerable decrease in errors associated with the transmission, conversion, display, or utilization of measurement data. Further, as more instrument systems are designed to utilize digital techniques, simplification and standardization of components will be possible. This in turn will augment reliability and simplify maintenance and replacement when necessary.

Automatic control of *continuous* production processes, such as oil refining, is well advanced, although far from complete. The extension and adaptation of automatic controls to the "unit" processes—the handling, manufacture, or treatment of discrete items—has already led to talk of the "automatic factory." Although economic factors and the shortage of instrument engineers limit this trend, the implications for increased productivity are profound.

Measurements and, therefore, instruments are fundamental to exploration of the physical world. Science progresses by the four steps of *cerebration, instrumentation, manipulation,* and *interpretation.* Every addition to the already wide repertory of scientific instruments contributes proportionally to the general advance of science. The interdependence of various branches of science is nowhere more evident than in the fruitful adaptation of the same instrument in quite different fields. For example, a simple bar magnet pushed through a coil of wire, for measuring the impact velocity in testing the resistance of ship structures to explosions, was adapted recently as a ballistocardiograph. More accurate measurements of heart activity are now possible, and a vigorous impetus has been given to research in this field of physiology.

For centuries, man has waged warfare by the process of *launching* destruction at his enemies—throwing stones, hurling spears, shooting arrows, aiming guns, or dropping bombs—but with the advent of automatic instrumentation, it becomes possible to *guide* destruction to the enemy. The probability of a hit in any one operation is thus enormously increased.

The guidance concept combines automatic detection—for example, radar, sonar, infrared—with automatic piloting and has led to homing torpedoes, guided missiles, and perhaps other weapons not disclosed. In these developments, military instrumentation has given much, and received more, from scientific and industrial instrumentation.

The spectacular destructiveness of atomic bombs has tended to overshadow the real significance of the guidance concept. Only through the successful and early achievement of complete and reliable means for automatically detecting and *intercepting* enemy ships, aircraft, or guided missiles may we hope, temporarily, to deter atomic aggression. Perhaps in this way, civilization can gain the time required to perfect the art of peaceful relations.

All scientists, engineers, warriors, and the informed public need to become better acquainted with *instrumentation* with respect to its effects on their own work and lives and its vast potential for increasing the military security and the productive capacity of the world.

W. A. WILDHACK, *President*
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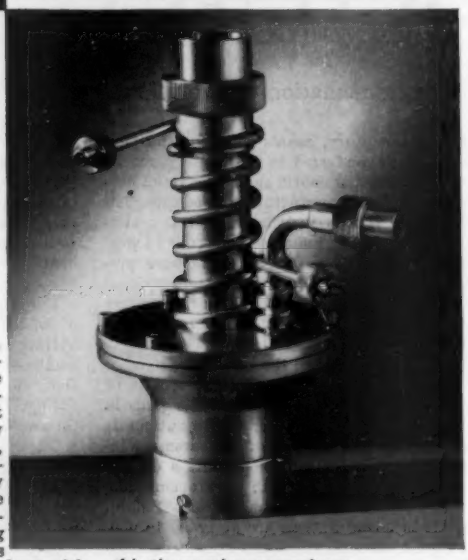

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Production and Use of High Centrifugal Fields

J. W. Beams

Department of Physics, University of Virginia, Charlottesville

THE action of a gravitational field and a centrifugal field on matter, for most purposes at least, may be considered to be essentially equivalent (*1*). Since the gravitational fields in regions near the earth are much smaller than the centrifugal fields that readily may be produced, it is common practice to express the magnitude of a centrifugal field in terms of the standard acceleration of gravity at the earth's surface. The purpose of this paper (*2*) is to describe a few typical experiments in which high centrifugal fields are used, together with some of the techniques employed.

In general, problems that require the use of high centrifugal fields fall into two principal categories. In the first type the centrifugal potential, which is proportional to $4\pi^2N^2r^2$, must be large; in the second type the centrifugal field, or $4\pi^2N^2r$, must be as intense as possible. N is the number of revolutions per second, and r is the radius of the rotor. As is shown later, with the present techniques the mechanical strength of the rotor is the factor that sets an upper limit to both the centrifugal potential and the intensity of the centrifugal field that can be produced with a given rotor. Both theory and experiment show that, for rotors of a given shape, the maximum stresses produced in the rotors are proportional to $4\pi^2N^2r^2$ or the square of the peripheral speed. Consequently, to produce a maximum centrifugal potential, the rotor must be carefully designed to reduce stress concentrations to a minimum.

The choice of rotor material depends primarily upon the load that the rotor must carry. If there is no load or if it is very light, the rotor material should have as large strength-to-density ratio as possible. If the load is not light, then the design of the rotor and selection of rotor material are more complicated. In general, tough materials are preferable to brittle ones if the strengths and densities are equivalent. Since both the centrifugal potential and the "bursting strength" depend directly upon the square of the peripheral speed of the rotor, the maximum centrifugal potential is independent of the radius of the rotor. On the other hand, since the centrifugal field is given by $4\pi^2N^2r$, to obtain a maximum field intensity, the radius of the rotor should be made as small as possible.

Although the maximum rotor speed is at present limited only by the rotor strength, in most experiments several other problems must be solved. In the first place, as a rotor is accelerated, it may pass through critical vibration frequencies which, unless they are damped, will destroy the rotor and the bearings. If the rotor is mounted in rigid bearings it must, of course, be carefully balanced. In many practical cases where the balancing cannot be done with enough precision the rotors are mounted on flexible shafts in a manner similar to the De Laval turbine (*3*) or in air bearings so that they can seek their own axis of rotation. In ordinary journal or ball bearings the frictional drag increases very rapidly with the speed of the bearing surface (*4*), so the radius of the bearing for high-speed rotors must be made very small, or the friction will become excessive. This frictional drag not only consumes a large amount of energy but introduces gyroscopic, heating, and other effects that are usually undesirable. Another difficulty encountered is the excessive heating of the rotor by the air friction on its surface. This is especially troublesome in sedimentation experiments where the rotor temperature must be held constant.

For rotors several centimeters in diameter the aforementioned problems have been solved successfully in several ways. Svedberg and his collaborators (*5*) solved the problems in their ultracentrifuge with an oil turbine drive and special oil-lubricated and -cooled bearings. The carefully balanced rotor is spun in hydrogen at reduced pressure. The hydrogen not only reduces the gaseous friction on the rotor but, because of its high thermal conductivity, conducts the heat that is generated to the walls of the chamber. Pickels and I (*6–8*) solved the foregoing problems in the vacuum-type ultracentrifuge by spinning the rotor in a vacuum. The rotor is mounted on the end of a long, very small diameter, flexible shaft that passes through a vacuum gland in the top of the chamber and is connected either to a small-diameter, air-supported, air-driven turbine or to an electric motor drive situated above the vacuum chamber. In this apparatus no appreciable heat is generated in the rotor, so not only does it remain at constant temperature when the chamber walls are properly thermostated, but the power required to drive it is very small. This vacuum-type ultracentrifuge has been improved by many different workers and for some time has been commercially available. Space does not permit the mention here of other methods that have been devised for spinning high-speed rotors, and reference must be made to more detailed reviews (*5, 8, 9*).

For several years a method of magnetically suspending and electromagnetically driving a rotor in a vacuum has been under development at the University of Virginia (*10*) which automatically solves the aforementioned difficulties (*11–15*). Also, rotors with diameters from 10^{-2} to more than 25 cm, and with weights from 5×10^{-5} to 2.5×10^{4} g have been used. The general method is illustrated by Fig. 1, which is a schematic diagram of an apparatus used for measuring the ten-

sile strengths of metals (*16*) as well as the tensile strengths of metal films as a function of their thickness (*17, 18*). The steel rotor is freely suspended inside a glass vacuum chamber by the axially symmetric magnetic field of the solenoid situated above the vacuum chamber. Figure 2 is a photograph of a 1½ in. steel sphere freely suspended with the vacuum chamber and drive coils removed. The vertical force on such a rotor is roughly equal to $M(dH/dx)$, where M is the magnetic moment of the suspended rotor and dH/dx is the vertical gradient of the magnetic field. In order to maintain the rotor suspended freely at a definite height, means must be provided for regulating the current in the solenoid. This may be accomplished in

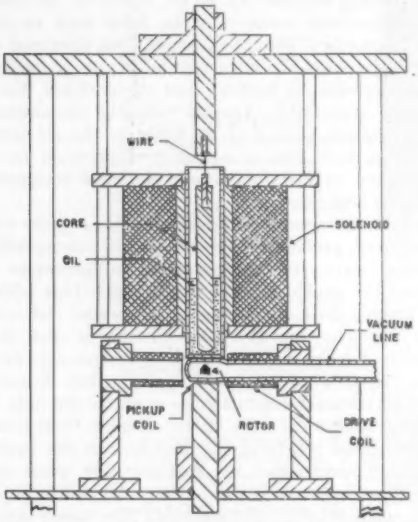

Fig. 1. Schematic diagram of magnetic suspension.

several ways (*14, 15*). In Fig. 1 a small pickup coil mounted on a plastic support below the glass vacuum chamber serves as the sensing element of a servocircuit that regulates the current through the solenoid in such a way that the rotor is held at the desired vertical position. The rotor automatically seeks the strongest part of the field, which is on the axis of the solenoid. However, if it is disturbed, it will oscillate around the axis. To prevent this the core of the solenoid is supported by a fine wire and thus hangs as a pendulum in a dash-pot of oil. If the rotor is disturbed, the core follows the horizontal motion of the rotor and damps it out. When the apparatus is properly adjusted, no movement of the rotor can be observed with a 50-power microscope focused on the rotor surface. For example, for use with rotors from 0.1 to 0.2 in. in diameter, a cylindrical steel rod core 3.5 in. long, 0.2 in. in diameter, suspended by a 0.25-in. length of 0.017-in. piano wire is satisfactory. The core is immersed to a depth of 1.2 in. in S.A.E. No. 10 motor oil contained in a flat-bottom glass tube.

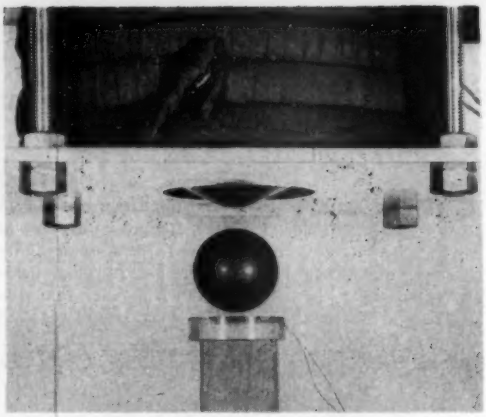

Fig. 2. Magnetically supported 1½-in. steel sphere.

The support solenoid L_1 (Fig. 3) consists of 20,500 turns of A.W.G. No. 30 enameled copper magnet wire wound on a 1.1-in. o.d. plastic tube. The outside diameter of the solenoid is 3.12 in. and its length is 2.63 in. Its direct-current resistance is roughly 1200 ohms, and its inductance is about 30 hy, which gives it a time constant of about 0.025 sec. The "pickup" coil L_2 consists of 12 turns of A.W.G. No. 34 copper wire bunch-wound with an inside diameter of 0.4 in. The support circuit is shown in Fig. 3. The pickup coil, L_2, is in the grid circuit of a partially neutralized, tuned-grid, tuned-plate oscillator that operates at a frequency between 5 and 8 Mcy/sec. A change in the vertical position of the rotor changes the Q value of the oscillator circuit and, therefore, the amplitude of the oscillations. The output of the oscillator is applied to the grid of a 6J5 tube in an "infinite impedance" detector stage (cathode follower), which does not load the oscillator. The d-c voltage appearing across the cathode resistor is an electric measure of the rotor height above the pickup coil. A portion of this voltage is picked off the cathode resistor and constitutes the control or "error" signal. In parallel with the cathode resistor is a resistance-capacitance differentiating circuit. The potential difference across the resistance of this network is proportional to the time rate of change of rotor height. The "error" and the

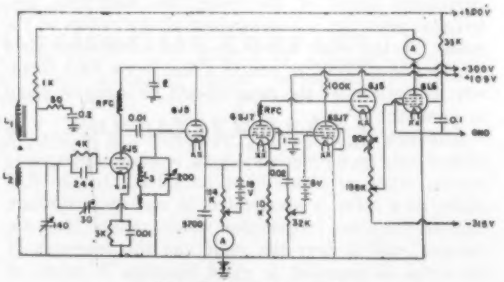

Fig. 3. Support circuit.

derivative or damping signals are separatively amplified, mixed, and applied to the grid of a second cathode follower stage. The combined signal is next applied to the grids of the 6L6 output stage and, hence, regulates the current through the support solenoid, L_1. It will be observed that separate means are provided for independently adjusting both the error and the derivative or damping signals, so that it is a simple matter to find the proper relative and absolute values to provide stable support for the rotor.

The rotor is spun by a rotating magnetic field in a manner similar to that of the armature of an induction motor or of a synchronous motor. If the rotor is not too large and a small amount of temperature rise of the rotor (order of 5°C) can be tolerated, the induction motor drive is preferred because of its simplicity; but, if the rotor temperature and rotor operating speed must remain constant, then it should be both accelerated and operated as a synchronous motor. When accelerated as a synchronous motor, the frequency of the rotating magnetic field is automatically increased at the same rate as the acceleration of the rotor. When at operating speed, the frequency of the rotating magnetic field is maintained constant by a crystal-controlled circuit. The rotating magnetic field is produced by alternating current in two pairs of drive coils outside the vacuum chamber, as shown in Fig. 4. Standard drive circuits are used to produce the alternating current in these coils (*14, 19*).

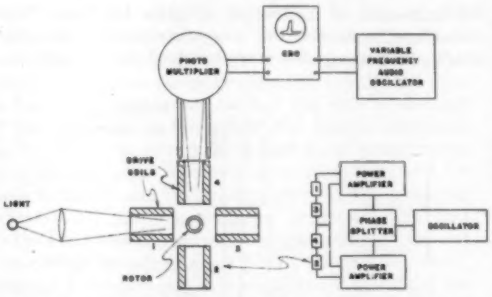

Fig. 4. Schematic diagram of drive circuit and method of measuring rotor speed.

Figure 4 shows a schematic diagram of a drive system and a method of measuring the rotor speed. If the rotor is to be accelerated in a way similar to that of the armature of an induction motor, the output of a fixed-frequency oscillator is fed to a 90-deg phase splitting bridge. Each phase is separately amplified and applied to one pair of drive coils, as shown. The drive coils are in parallel with capacitors of the proper magnitude to give resonance at the desired drive frequency. Because of the high electric resistance of the rotor, the torque is comparatively large, even when the rotor is at rest or turning slowly. During the acceleration period the rotor is heated by the eddy currents induced by the rotating magnetic field; but, with the acceleration rates used in practice, the temperature rise is usually only a few degrees. The rotor temperature may be measured by its thermal radiation.

Since the supporting magnetic field is axially symmetric, the rotor friction caused by the magnetic suspension itself should be exceedingly small. This has been found to be the case (*14, 20*). The observed rotor friction can be entirely accounted for by the gaseous friction on the spinning rotor. By maintaining the gas pressure surrounding the rotor below about 10^{-6} mm-Hg, this gaseous friction is very small; so that, in order to stop the rotor in a reasonable time, the direction of rotation of the magnetic field must be reversed and the rotor driven to rest. For a spherical rotor of radius r, density d, and absolute temperature T, surrounded by a gas at low pressure of molecular weight M and pressure p, it can be shown that approximately

$$\log_e \frac{N}{N_0} = \frac{-5p}{rd}\left(\frac{M}{2\pi RT}\right)^{1/2}(t - t_0),$$

where N_0 is the number of revolutions per second at time t_0, and N is the number of revolutions per second at time t. As a matter of fact, by measuring the deceleration of the rotor while it is coasting freely, the apparatus serves as an excellent absolute low-gas-pressure gage. With the gas pressure below 10^{-6} mm-Hg the friction is so small that the rotor will accelerate as an induction motor to the speed corresponding to the frequency of the oscillator and then "lock in" and spin as a synchronous motor. In practice, when it is desired to spin the rotor at extremely constant speed and a small temperature rise can be tolerated during the acceleration period, as in the case of a rotation mirror, the rotor is accelerated as an induction motor to just above the running speed. The oscillator is then connected to a crystal control which holds it constant to the order of 1 part in 10^8, and the rotor speed settles down and "locks in." In a few minutes all observable "hunting" vanishes, and the rotor speed is at least as constant as the frequency of the oscillator (*19*). The rotor speed is determined by reflecting or scattering light off the rotor into a photomultiplier tube, as shown in Fig. 4. A mark placed on the rotor causes the photomultiplier output to be periodic with a repetition rate equal to the speed of the rotor. This signal is amplified and compared with that from a calibrated variable frequency oscillator on a cathode-ray oscilloscope screen. For the most precise determination of rotor speed, the output of the photomultiplier is compared with the broadcast signal of station WWV of the National Bureau of Standards.

By spinning a rotor until it explodes, the maximum strength of the rotor material can be computed if the rotor is properly designed. For spherical rotors the maximum stresses are at the center and, therefore, in a region not containing a surface. Table 1 gives the results obtained with a series of carefully selected steel ball bearings just before they exploded (*16*). They are the maximum values obtained. It will be observed that all the rotors exploded at approximately the same peripheral speed, which is in accord with theory, and also that the highest centrifugal acceleration, which

Table 1. Bursting speeds of spherical steel rotors.

Rotor diam. (mm)	Rotor speed (10^3 rev/min)	Peripheral speed (10^3 cm/sec)	Centrifugal acceleration ($10^6 g$)	Maximum calculated stress (10^3 lb/in.^{2})
3.97	4,420	96	47.1	410
2.38	7,410	92.5	72	385
1.59	12,660	105	143	498
0.795	23,160	96.5	240	420
0.521	37,980	104	428	488
0.398	48,000	100	515	454

was just greater than a half-billion times gravity, was obtained with the smallest rotor. The calculated maximum stresses that occur at the center were calculated by elastic theory (*21*) and were not corrected for plastic flow.

If a thin film of material is uniformly deposited on the complete cylindrical surface of a rotor such as that shown in Fig. 1, it can be shown (*17*) that $4\pi^2N^2r^2d = T + Ar/h$, where N is the rotor speed in revolutions per second, r is the rotor radius, d is the density of the deposited film, h is the film thickness, T is the tensile strength of the deposited film, and A is the adhesion (adhesive force per unit area). Since the second term on the right contains r/h, while the first does not, by using rotors of different radii both the tensile strength and adhesion can be obtained. Also, by depositing the films on the rotor surface in patches, the "hoop strength" vanishes, and the adhesion is obtained directly. However, in order to obtain the tensile strength of the films, small rotors were used in order to make r/h as small as possible; and a process of thermal cycling was applied to the rotor containing the deposited film in such a way that the adhesion was reduced to a negligible value. A series of measurements made on electrodeposited silver films as a function of their thicknesses showed that for film thicknesses greater than about 3×10^{-5} in. the tensile strengths were approximately the same as found in bulk silver and independent of the thickness. However, between about 3×10^{-5} and 10^{-5} in. the tensile strength of the films increases manyfold (*17, 18*). This result is probably to be expected from the dislocation theory of metals. The experiments on the adhesion of silver films to metals are less clear, but there is an indication that the adhesion begins to increase at thickness of roughly half that where the tensile strength increases.

If the rotor of Fig. 1 is made of high-strength ferromagnetic material with properly ground flat mirror surfaces, it becomes an excellent high constant-speed rotating mirror. A rotor with six flat mirror surfaces each 0.25 in. wide has been operated at 20,000 rev/sec for long periods of time (*19*). The rotor speed was controlled by a thermostated crystal, and no variation in speed could be measured. The speed was determined to about 1 part in 10^7. The accuracy was limited by the estimated reliability of the signal received from WWV. This rotating mirror is almost ideal for studying phenomena that radiate light in short intervals of time. Also, it should be well suited for velocity-of-light measurements as soon as suitable light paths can be measured with accuracy comparable to that of the rotor speed.

The fact that the tensile strength of silver films increases rapidly when the thickness is decreased below 3×10^{-5} in. at room temperature naturally raised the question of whether or not this effect will occur at very low temperatures and, if so, at greater or smaller thicknesses. Figure 5 is a schematic diagram of an apparatus at present being used to study the tensile strength of films and of metal crystals at liquid nitrogen and liquid helium temperatures. The rotor is freely suspended in a glass vacuum chamber surrounded by two concentric Dewar flasks. The inner flask contains liquid helium and the outer liquid nitrogen. The support solenoid surrounds the outer flask. The horizontal damping of the rotor is provided by a small, steel needle attached to a small cylinder of plastic foam. The support circuit is essentially the same as that previously described. With some modification of the method, the rotors also may be suspended and spun up to temperatures where the rotor material loses its ferromagnetic properties.

Perhaps the most important use of high-speed rotors is in centrifuges for separating material and for the determination of molecular weights. Of these two centrifuge problems, the measurement of molecular weights is perhaps the more exacting on the appara-

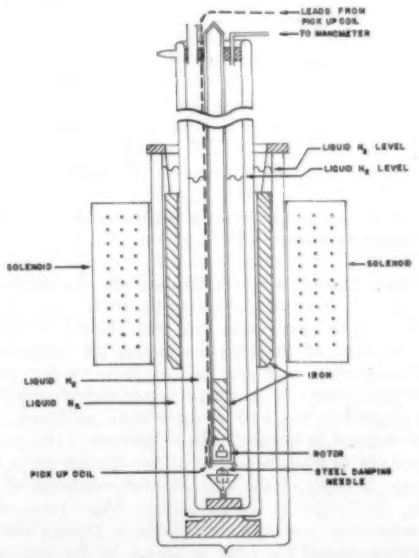

Fig. 5. Method of magnetically supporting rotors at low temperatures.

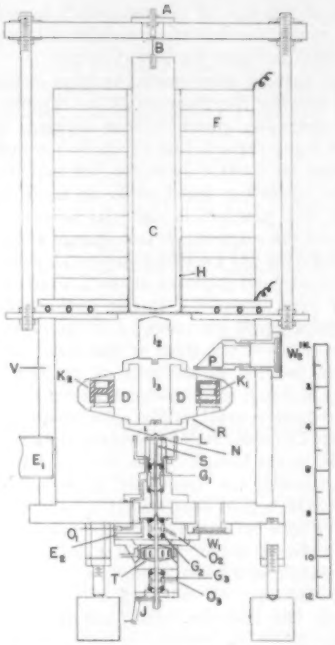

Fig. 6. Magnetically supported ultracentrifuge.

tus. Therefore, a brief description of the magnetically supported ultracentrifuge (*22*) is given. There are two principal methods of determining the molecular weight of a substance by centifuging (*5*). In the first, or rate-of-sedimentation, method the rate of settling of the substance in the centrifugal field is measured. In the second, or equilibrium, method the centrifuging is continued until the sedimentation is balanced by back diffusion, and the concentration of the substance is measured at various radial distances. The first method requires a relatively high centrifugal field and a centrifuging time of a few hours, whereas the second employs a relatively less intense centrifugal field but a centrifuging time of several days or weeks. In the past the first, or rate-of-sedimentation, method has been used more widely where the molecular weights are large enough to give an appreciable rate of sedimentation because of the difficulty of maintaining the speed and temperature of the centrifuge rotor extremely constant for long periods of time. On the other hand, the theory used in the second, or equilibrium, method is much more reliable because it is based directly upon thermodynamics rather than upon Stokes' law, as in the case of the rate-of-sedimentation method. Furthermore, with the same rotor speed the equilibrium method may be used for much smaller molecular weights.

Since magnetically suspended rotors in a high vacuum have a very small frictional resistance and are freely suspended, their temperature may be accurately maintained constant by thermostating the vacuum chamber walls. Also the rotor speed can be accurately controlled. Consequently the magnetically suspended rotor should make an excellent ultracentrifuge.

Figure 6 is a diagram of the ultracentrifuge and Fig. 7 shows the ultracentrifuge rotor with the vacuum chamber removed. The rotor R is freely suspended inside the brass vacuum chamber V by the solenoid F situated above the chamber. It is accelerated to operating speed by the air turbine T below the chamber. The turbine is connected to the rotor by the small diameter shaft S that passes through the vacuum-tight oil glands G_1 and G_2. The shaft S fits into a slot in the rotor; and, when the rotor reaches the desired operating speed, it is pulled out. This disconnects the rotor from the drive and allows it to coast freely during the period of observation of the sedimentation. The sedimentation is observed optically by passing a beam of light through window W_1, the centrifuge cell K_1, the right-angle prism P, and out through window W_2.

The rotor R shown in Figs. 6 and 7 is made of Duralumin with a steel core and weighs about 10 lb. More recent rotors are about the same shape and made of alloy steel. They weigh about 30 lb, and the distance from the axis of rotation to the center of the centrifuge cell K_1 is 6.5 cm. The support solenoid F consists of 28,000 turns of No. 22 enameled copper magnet wire and has a resistance of about 1200 ohms. The operating current in the solenoid is between 150 and 350 ma. The cylindrical steel core C of the solenoid ($1\frac{1}{16}$ in. in diameter and 12 in. long) is suspended by a small wire B, as shown in Fig. 6. The lower end of C hangs in a dash-pot of No. 40 motor oil which damps any swinging motion. This damps any horizontal motion of the rotor R in a way similar to that in

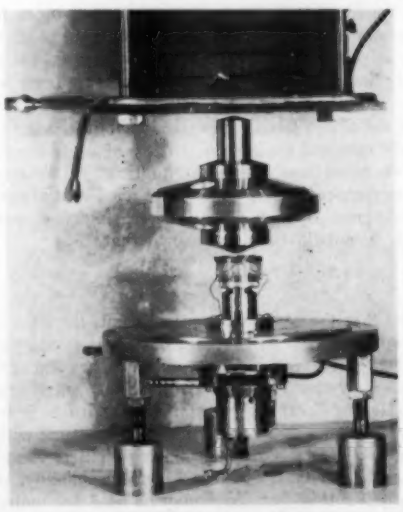

Fig. 7. Magnetically supported ultracentrifuge rotor with vacuum chamber removed.

the apparatus of Fig. 1. Incidentally the core C can, of course, be permanently magnetized if desired. Sometimes this has been found to be advantageous. The support circuit is similar to that shown in Fig. 2, and reference should be made to previous papers for details (*22, 23*).

With the air pressure the order of 10^{-6} mm-Hg and the 30-lb rotor coasting freely at 300 rev/sec, it required approximately 3 days to decelerate 1 rev/sec. This very slow rotor deceleration allows the rotor speed to be measured by comparing it with the broadcast signal from station WWV to 1 part in 1 million. The temperature of the walls of the chamber and, hence, that of the rotor is held constant to better than 1 part in 10,000 for as long as desired. With this equilibrium method the molecular weight M_e is given by the relationship (*5*).

$$M_e = \frac{2RT \log_e (C_1/C_2)}{(1 - d\bar{V}) 4\pi^2 N^2 (r_1^2 - r_2^2)},$$

where C_1 and C_2 are the concentrations at the radii r_1 and r_2, respectively, T is the absolute temperature, $\bar{V}$ is the partial specific volume, d is the density, and N is the number of revolutions per second. This formula is for a dilute ideal incompressible solution. With N measured to 1 part in 10^6 and T to 1 part in 10^4, the values of C_1 and C_2 are the least precisely known values in the relationship. The partial specific volume $\bar{V}$ and density d are measured in separate experiments, so they need not be considered here. In view of this, a great deal of effort has been devoted to improving the precision with which the concentration in the centrifuge cell can be measured. First, it was necessary to develop a centrifuge cell (*24*) in which the optical distortions were balanced out; and, second, an interferometer method was developed for determining the refractive indexes of the solutions while the rotor was spinning (*25*). From these refractive index measurements the values of C_1 and C_2 may be much more precisely determined, but they are still the least accurately known of the quantities measured while the rotor is spinning.

In the true equilibrium experiments the rotor speed is held constant during the process of centrifuging. It will be noted that, although "hunting" of the rotor is entirely absent in the afore-mentioned centrifuge, the rotor speed is very slowly decreasing (0.3 rev/sec day). Archibald (*26*) has shown that, if

$$\frac{1}{N} \cdot \frac{dN}{dt} \Big/ 4\pi^2 N^2 S << 1,$$

where S is the sedimentation constant, then the equilibrium condition will remain once it is established in the centrifuge cell. These conditions are satisfied in practice by the foregoing equilibrium centrifuge. As a matter of fact, the equilibrium condition is established in the centrifuge cell in much less time with the rotor speed very slowly decreasing than if the speed were held constant, which is a considerable advantage. In practice this centrifuge may be used for molecular weight measurements over the range from 10^2 to 10^7 molecular weight units with excellent precision. For example, in the case of sucrose, which is in the most difficult range, the molecular weight values obtained are accurate to three significant figures.

The air-turbine drive shown in Figs. 6 and 7 was adopted because the rotor could be rapidly accelerated to operating speed without heating. However, there are many experiments in which it would be better to have an electric drive for the centrifuge with which the operating speed could be made extremely constant. The problem is difficult, because the temperature of the rotor should not change as a result of the drive during the acceleration period. Such a drive has been under development at the University of Virginia for some time (*20*). In one method (*27*) small permanent magnets are mounted in the lower part of the rotor at about one-third of the rotor radius with their axes parallel to the axis of rotation and are driven by a rotating magnetic field below the rotor with a frequency equal to the rotor speed but slowly increasing. The rotor thus accelerates as a synchronous motor and is not heated. When the rotor reaches the operating speed, the frequency of rotation of the magnetic field is held constant. It is believed that the ultracentrifuges here described will be useful, not only for the measurement of molecular weights, but also for the measurement of molecular weight distributions, and that they may be used not only as equilibrium centrifuges but also for rate-of-sedimentation measurements.

Space does not permit the further review of many more uses of the magnetically supported, high-speed rotors; but it is believed that their use should be seriously considered whenever high or constant rotor speed is required or the bearing friction must be low. Finally, for some cases where the control circuits are not feasible, the diamagnetic properties of superconductors may be used for supporting spinning magnets. When magnetic fields cannot be used electrostatic suspensions are probably feasible.

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Scintillation Spectrometer with Improved Response

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THE physical electronics group at the Oak Ridge National Laboratory has constructed an improved scintillation spectrometer that is one step closer to the ideal gamma-ray spectrometer, namely, one that would give one single peak in its response for a monoenergetic gamma ray and would have nearly 100-percent efficiency.

The usual scintillation counter produces a pulse distribution for a monoenergetic gamma ray that includes, in addition to a peak representing the full energy of the gamma ray, a continuous distribution of pulses from zero size to a well-defined upper limit lower than the principal peak. This continuous distribution is caused by gamma-ray quanta that interact with the phosphor by the Compton process wherein an electron and a scattered gamma-ray photon share the energy of the original quantum. The scattered photon may escape from the phosphor; if it does, only the smaller pulse caused by the electron is recorded. A similar escape of energy often follows a pair-production process, wherein the created electron pair shares the energy left over in the original quantum above the amount (1.02 Mev) required to produce the electron and positron of the pair. After both members of the pair are stopped in the phosphor, the positron combines with some nearby electron to produce by annihilation two photons of 0.511-Mev gamma ray. One or both of these photons might escape from the phosphor without absorption.

The response of an ordinary scintillation counter to gamma rays is shown in Figs. 1*a* and 2*a*. The phosphor in the ordinary counter was a right circular cylinder of sodium iodide activated with thallium, 1½ in. in diameter and 1 in. high. Figure 1*a* shows the response to the radiations from Zn^{65} which gives a gamma ray of 1.114 Mev and a very weak positron emission (resulting in a small amount of annihilation radiation). The peak at 640 pulse-height divisions is produced by complete absorption of the 1.114-Mev gamma ray. The peak at 300 pulse-height divisions is produced by the 0.511-Mev annihilation photons from the β^+ emission. The broad continuum extending up to about 500 divisions is the Compton electron-pulse distribution where the scattered photons have escaped.

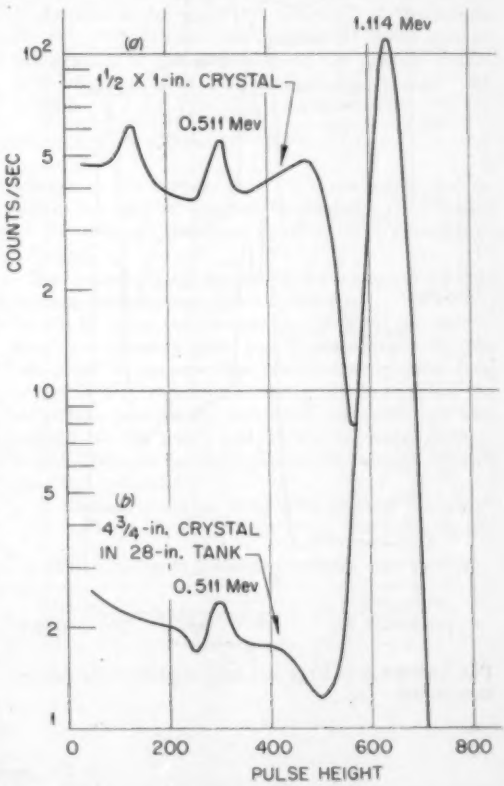

Fig. 1. Response of large and small crystals to the gamma rays of Zn^{65}.

The peak at 130 divisions is produced by radiation scattered from the surrounding objects.

Figure 2*a* similarly shows the response of the small phosphor to the gamma rays of Co^{60} (1.16 Mev and 1.32 Mev).

The largest sodium iodide crystal that we have is equivalent to a sphere 5¼ in. in diameter. This crystal with its 5-in. photomultiplier was placed in a reentrant thin-walled tube in the center of a large iron tank containing a solution phosphor (Fig. 3). Four 5-in. photomultipliers look at the solution phosphor, and the reentrant tube is stoppered with a small tank of solution phosphor looked at by a fifth photomultiplier. The pulse spectrum from the sodium iodide counter was examined by a multichannel analyzer with the output from the solution phosphor counter in anticoincidence so that no pulse from the central detector

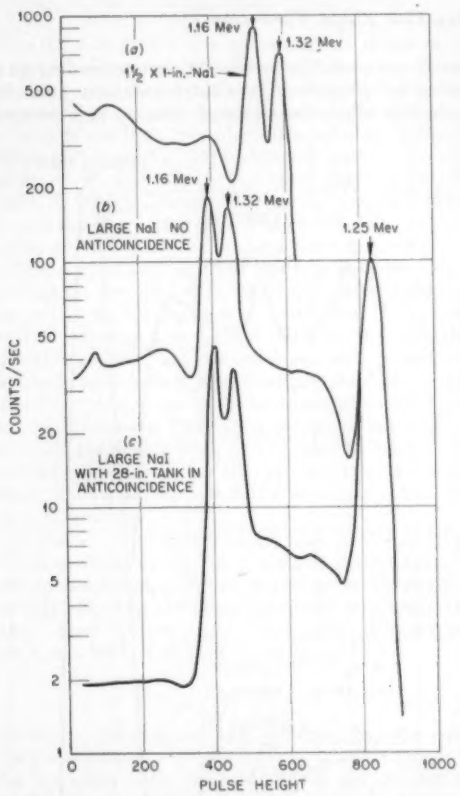

Fig. 2. Response of large and small crystals to the gamma rays of Co^{60}.

Fig. 3. Coincidence tank counter.

would be counted if there were also a scintillation in the liquid.

The solution phosphor is so large that most of the secondary photons that escape from the sodium iodide crystal are detected in the solution and the smaller pulse in the NaI counter is not recorded.

Figure 1*b* shows the response of the large crystal to the Zn^{65} gamma rays from a source placed in a hole drilled to the center of the crystal. Note the great reduction of the Compton distribution. Figure 2*b* shows the response of the large crystal to the Co^{60} radiation when the tank is not in anticoincidence. The larger crystal alone gives considerable reduction of the Compton distribution. The two gamma rays of Co^{60} are in cascade and are produced with negligible delay so that very frequently both gamma rays are completely detected, giving rise to a pulse representing the *sum* of the gamma-ray energies (2.5 Mev).

The lower curve (Fig. 2*c*) shows the effect of adding the anticoincidence circuit. The Compton distribution is greatly reduced, and the two peaks representing the single gamma rays, with the other member of the cascade escaping entirely, are also strongly reduced because of the detection of the escaping member in the tank.

A somewhat larger tank would absorb essentially all the radiation escaping from the central crystal, and only those pulses would be recorded that represent complete absorption in the crystal of all radiation from each event.

Instrumental Drift*

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THE developments in instrumentation and control devices in recent years are manifest in most laboratories. These advances have brought better measurements and have eased the labor of obtaining and recording them. Furthermore, improved instrumentation often has made it feasible to take more measurements. There is another consequence, one that many experimenters will consider an advantage, to be credited to better instruments. Better measurements, and more of them, have made it possible to interpret most data without recourse to statistical techniques.

Experimenters habitually try to select instruments and to control measurement procedures in order to get reproducible measurements that are good enough for their immediate purposes. These purposes generally fall into two classes: either the experimenter wants to keep the uncertainty in the result below some specified value, or else he wants to be able to distinguish between objects if these differ by some minimum amount in the measured property. If the worker succeeds in these respects, the interpretation of the data is simplified, because the uncertainties in the measurements can be, and usually are, ignored.

Apparently it is easier for many people to obtain elaborate and expensive control devices than it is to delve into the subject of the statistical design of experiments. Or they may be unaware that statistical design can bring the same kind of improvement in the data that comes from providing a uniform environment and will do this with little or no expense. The ideal measurement procedure should give results that the experimenter can accept without worrying about their reliability. The experimenter is then free for the task of studying the relationships that are involved in his scientific problem. In most cases the measurements are subject to random and other unknown sources of error that may either obscure relationships or even give the appearance of relationships when in fact there are none.

A good place to introduce statistics is in the preliminary trials an experimenter makes to assure himself that his apparatus and instruments are in a satisfactory operating condition. Consider the question of whether or not the instrument is subject to drift. Drift is usually explored by making a series of repeated measurements on the same object. Another question then plagues the worker. How can these repeated measurements be made independent of one another? How can the operator "forget" previous readings so that subsequent readings will not be influenced by earlier ones? These matters will be considered later.

Suppose the experimenter has made a series of measurements on the same object and has plotted the values as ordinates against the serial numbers of the measurements. A line drawn parallel to the x-axis with y equal to the average of all the readings will provide a visual test to detect trends in the sequence of readings. The experimenter would like to have the measurements indiscriminately scattered about the line and confined between two bracketing parallel lines as close as possible to the average line. If there is a pronounced trend, the visual test will reveal it. On the other hand, the experimenter may not be sure. Here, then, is the opportunity to use an objective statistical criterion to bolster his own judgment.

Table 1 lists measurements $y_1, y_2, \ldots, y_n$ in the order in which they were obtained. Two quantities, S^2 and D^2, may be computed from the observations in Table 1. The ratio of D^2 to S^2 should fall within predictable limits about the integer 2 if the results are free from trends. The quantity S^2 is the sum of the squares of the deviations of the plotted points from the horizontal line through the average. The formula

$$S^2 = \Sigma(y_i - \bar{y})^2 = \Sigma y_i^2 - \frac{(\Sigma y_i)^2}{n},$$

where $\bar{y}$ is the average value, is a convenient way to obtain this sum of squares. Incidentally, the estimate of the standard deviation for these measurements is $\sqrt{S^2/(n-1)}$.

The quantity D^2 is the sum of the squares of the differences between successive measurements: $D^2 = \Sigma d_1^2$. It will be noted that the interval between two *successive* measurements gives only slight opportunity for the trend to operate. The d's are nearly what they would be if there were no trend at all. In contrast, the deviations between the individual y's and $\bar{y}$ are susceptible to the trend, and S^2 will be larger than it would otherwise be. The value of the ratio D^2/S^2 will then fall below 2.0.

It remains to set up some criterions for the allowable ratio of D^2/S^2. In any set of observations, the

Table 1. Successive differences between measurements.

Order of measurement	Measurement	Successive difference
1	y_1	$d_1 = y_1 - y_2$
2	y_2	$d_2 = y_2 - y_3$
3	y_3	
.		
.		
.		
$n-1$	y_{n-1}	$d_{n-1} = y_{n-1} - y_n$
n	y_n	

errors of measurement may, by chance, fall into suspicious configurations even when there is no trend. This is more likely to happen if the series is a short one so the limits for the ratio D^2/S^2 will depend on the number n of measurements.

Bennett (*1, 2*) has adapted some tables, published by Hart (*3*), that list limits of D^2/S^2, each of which will be exceeded on the average in 1 out of 20 sequences (or 1 in 100) for sequences that are not afflicted by any trend whatsoever. Thus, if a particular sequence does transgress these boundaries, it is usual to consider this as evidence of a trend rather than as a very improbable occurrence. Table 2 shows some specimen values of the limits taken from Bennett's table.

Sufficiently low values of the ratio D^2/S^2 are evidence of a trend. Overly large values of D^2/S^2 also indicate that the data depart from the expected random scatter. One way that the ratio may be inflated is by changing the zero setting or making other adjustments between successive readings. In general these adjustments will lead to a succession of large differences between successive readings and therefore will inflate D^2.

The following 20 determinations of the percentage of nickel were made on 20 successive segments of a rod of alloy by a spectrochemical procedure: 42.4, 40.8, 41.0, 41.8, 40.3, 40.8, 40.8, 39.6, 41.5, 41.5, 40.2, 40.4, 41.0, 42.2, 39.4, 41.0, 41.4, 40.6, 42.4, 40.8. It was important to know whether there was a trend along the rod. The computation for D^2/S^2 gave 31.32/12.99, or 2.41. The quotient is well within the listed limits for the ratio with n equal to 20, and there is no convincing evidence for a trend. The scatter of the data about the average line is shown in Fig. 1.

One obvious way to avoid the effect of remembering previous readings, referred to earlier, is to change the object being measured. At first thought, this would appear to make it impossible to detect any trend or drift in the measuring equipment. Certainly each reading will now depend on which object is measured and, if there is a drift, where the measurement is in the series. Such entanglement of effects can, however, be readily resolved if the objects are measured in an appropriate sequence. The devising of these sequences is one of the activities in the field of statistical design.

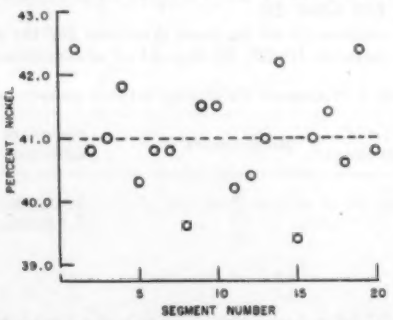

Fig. 1. Percentage of nickel in successive segments of an alloy rod.

Five objects, *A, B, C, D,* and *E,* may be available, and each could be measured four times in a sequence of 20 measurements. The problem is to set up a schedule that will still make it possible to detect the trend. Obviously nothing will be gained if four measurements are made on *A,* then four measurements on *B,* and so on. The memory difficulty is still present, and the values obtained for each object are inseparably combined with the drift, if any, in the instrument.

An alternative arrangement that begins to get into the problem is one that divides the sequence into four parts, each part containing all five objects. Thus,

BAEDC | BEDAC | EDCBA | CAEDB

The order of the objects within each part should be random. Now the average for the five objects in a particular block should be the same as the average in any other block except insofar as a trend happens to be present. In a coarse way, these averages, when plotted opposite 3, 8, 13, and 18, begin to reveal any instrument trend. The actual trend in any block that would be revealed by five ordinates is replaced by the average of these ordinates and centered in the middle of the block.

A modification of the afore-mentioned procedure will delineate the presumably rather smooth curve that corresponds to the true trend line during the measurements. The curve can be approximated by drawing short horizontal lines in a stepwise fashion along the curve. Each short horizontal line replaces the slant and slightly curved line in its vicinity. This horizontal line is located at a height equal to the average ordinate of the curve in the narrow band covered by the curved short line. If there were some way to determine the position of these short horizontal lines, the curve, or trend line, would stand revealed. It is better to have as many short lines as possible and to have them as short as possible. Ten short lines, each covering two measurements, afford a better approximation to the trend curve than four lines, each covering five measurements.

A difficulty then arises in the fact that the pair of objects used in any part will not be the same as the pair used in some other part of the curve. This would appear to make the averages for each pair useless for comparison, because the objects are different. If the pairs are formed in an appropriate manner, there is a simple procedure for comparing the parts, despite the fact that different objects occur in the different parts.

Five objects can be used to form 10 different pairs, each object appearing in four of the pairs.

Part	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*
Object	*AB*	*DE*	*BC*	*EA*	*CD*	*EB*	*AC*	*BD*	*CE*	*DA*

These pairs break the trend curve into 10 parts. The order of the pairs is immaterial. The purpose is to determine the average values of the ordinates for each of the 10 parts, just as if all the measurements had been made on one object.

First use is made of the fact that the objects in any part, say *A* and *B* in part *a,* appear in six other parts. Thus, by using object *A,* the differences between part

Table 2. Limits for the ratio D^2/S^2.

No. in series n	1 in 20		1 in 100	
	Lower	Upper	Lower	Upper
5	0.82	3.18	0.54	3.46
10	1.06	2.94	0.75	3.25
15	1.21	2.79	0.92	3.08
20	1.30	2.70	1.04	2.96

Table 3. Determination of average value of ordinate a.

Using object	Difference between ordinates
A	$3(a-d) = x_1$
A	$3(a-g) = x_2$
A	$3(a-j) = x_3$
B	$3(a-e) = x_4$
B	$3(a-f) = x_5$
B	$3(a-h) = x_6$
C	$(c+g)-(e+i) = x_7$
D	$(h+j)-(b+e) = x_8$
E	$(d+f)-(b+i) = x_9$
Sum	$18a-2(b+c+d+\ldots+j) = \Sigma x_i$
Equivalently	$20a-2(a+b+c+\ldots+j) = \Sigma x_i$
And	a – (average ordinate over all parts) $= \Sigma x_i/20$

Table 4. Comparison of actual and calculated instrument drift.

Reading number	Instrument drift	Object and its value		Observed reading	Part	Calculated deviation from mean drift	Calculated drift*
1	0	A	75	75	a	– 2.9	2.1
2	4	B	85	89			
3	7	D	55	62	b	3.7	8.7
4	10	E	45	55			
5	13	B	85	98	c	8.5	13.5
6	15	C	65	80			
7	17	E	45	62	d	12.0	17.0
8	17	A	75	92			
9	16	C	65	81	e	10.7	15.7
10	15	D	55	70			
11	13	E	45	58	f	6.0	11.0
12	10	B	85	95			
13	7	A	75	82	g	0.5	5.5
14	4	C	65	69			
15	0	B	85	85	h	– 6.2	– 1.2
16	– 3	D	55	52			
17	– 7	C	65	58	i	–14.1	– 9.1
18	–10	E	45	35			
19	–13	D	55	42	j	–18.2	–13.2
20	–15	A	75	60			

* It is possible to determine this calculated drift only when the mean value of drift is known or determinable. In this example, the value 5.0 is used for the average of all ordinates from the curve of Fig. 2.

a and parts d, g, and j can be estimated; by using object B, the differences between part a and parts e, f, and h can be estimated. This leaves parts b, c, and i to be considered. Notice that, by using object C, parts c and g can be compared with parts e and i; by using object D, parts h and j can be compared with parts b and e; and finally E gives parts b and i in terms of parts d and f. The lower-case letters are used to represent the average ordinates of the parts. These differences are shown in Table 3.

When a result located in a part, say d, is subtracted from a result in another part, say a, using the *same* object (A), the value of A, whatever it may be, drops out. The first six differences tabulated are multiplied by 3 to bring the sum to the form shown in Table 3. All letters other than a have the coefficient -2. The ordinate for part a, multiplied by 18, has twice the sum of the ordinates for all other parts subtracted from it, and Σx_i is the result. The difference is unchanged if twice ordinate a, or $2a$, is added and subtracted. Division by 20 then gives the ordinate for a when added to the *average* ordinate over all parts.

A constructed example illustrates how well the scheme works. Suppose an instrument drifts as shown in Fig. 2. The curve shows the drift expressed in units of the terminal figure recorded. The instrument starts out and drifts so that after a time the readings are too high by about 17 units in the last place; then the trend reverses and drops until at the end readings are too low by about 15 units.

Imagine that five objects, A, B, C, D, and E, are available and that these, when measured, should give the values 75, 85, 65, 55, and 45, respectively. By reading from the drift curve and by assigning the values for the objects, one obtains a sequence of 20 readings, as shown in the fourth column of Table 4.

The only information that is assumed available for the statistical analysis is the column of observed readings together with the identities of the objects. It is assumed that the objects themselves do not change in value during the observations. The calculation of the average drift corresponding to part a, using the data of Table 4 and the equations of Table 3, is shown in Table 5.

Table 5. Calculation of average drift corresponding to part a.

Using object	Difference between ordinates
A	$3(75-92) = -51$
A	$3(75-82) = -21$
A	$3(75-60) = 45$
B	$3(89-98) = -27$
B	$3(89-95) = -18$
B	$3(89-85) = 12$
C	$(80+69)-(81+58) = 10$
D	$(52+42)-(62+70) = -38$
E	$(62+58)-(55+35) = 30$
Sum	$18a-2(b+c+d+\ldots+j) = -58$
Equivalently	$20a-2(a+b+c+\ldots+j) = -58$
And	a – (average ordinate over all parts) $= -58/20$
Therefore calculated deviation from mean drift $= -2.9$	

Table 6. Determination of average value of ordinate b.

Using object	Differences between ordinates	
	In symbols	Using data of Table 4
D	$3(b-e)=x_1$	$3(62-70)=-24$
D	$3(b-h)=x_2$	$3(62-52)=30$
D	$3(b-j)=x_3$	$3(62-42)=60$
E	$3(b-d)=x_4$	$3(55-62)=-21$
E	$3(b-f)=x_5$	$3(55-58)=-9$
E	$3(b-i)=x_6$	$3(55-35)=60$
A	$(d+j)-(a+g)=x_7$	$(92+60)-(75+82)=-5$
B	$(f+h)-(a+c)=x_8$	$(95+85)-(89+98)=-7$
C	$(e+i)-(c+g)=x_9$	$(81+58)-(80+69)=-10$
Sum	$18b-2(a+c+d+\ldots+j)=\Sigma x_i$	$=74$
Equivalently	$20b-2(a+b+c+\ldots+j)=\Sigma x_i$	$=74$
And	b – (average ordinate over all parts) $=\Sigma x_i/20$	$=74/20$
		Calculated deviation from mean drift $=3.7$

To calculate the ordinate for b, we must set up another series of differences similar to the series used for the calculation of a (Table 3). These new differences are given in Table 6.

In setting up the series, note that the objects appearing in part b are objects D and E. Therefore the first 3 differences (x_1, x_2, x_3) are obtained by taking the value of object D in part b and subtracting from it the respective values of object D in the other three parts in which it appears. The next three differences (x_4, x_5, x_6) are obtained using the values of E in similar fashion. The difference x_7 is obtained by taking the sum of the values of A in the two parts where A appears with D and E and subtracting the sum of the two values of A that appear with B and C.

Similar sets of differences must be set up for all 10 parts in order to calculate the ordinates. In each instance the sum of all nine equations will be of the form shown in the sets given for a and b and, therefore, will provide a check that the proper differences have been set up. As a further check, when all 10 values of deviation from mean drift have been calculated, their sum should equal 0.

The numerical procedure outlined in the preceding paragraphs, leads to the estimates shown in the last column of Table 4. These, unavoidably, apply to both observations in the pair to which they are attached. Inspection reveals that the calculated drift is in excellent agreement with the averages of the two drifts recorded for each pair in the second column. Furthermore, by the pattern of deviations from mean drift (Fig. 2), the drift of the instrument stands revealed through the overlay of the different objects measured.

The drift curve was plotted on the assumption that the 20 observations were taken at equal intervals of time. This restriction may be relaxed, provided that the two observations forming any pair are taken in close succession and provided that the times are recorded. The x-axis becomes a time scale and the average ordinate for each part is located at the average time for the two observations.

One of the merits of using different objects is the fact that the observer cannot anticipate the next reading and this assists in the attainment of objectivity in the readings. This objectivity is particularly desirable in the matter of estimating the precision of the readings. Precision is usually estimated from immediately successive readings on the same object, and it is difficult to avoid forming an optimistic appraisal of the precision. The present scheme also makes possible an estimate of the precision. The numerical details are available (*4–7*).

So far all the emphasis has been placed on the performance of the instrument. The instrument will be used to measure objects, and it is reasonable to inquire whether the 20 observed readings in Table 4 can also be used to estimate the values of the five objects.

The pairs were formed in all possible ways from the five objects. Consequently, any given object has been matched with the four others in some four of the 10 parts. And, most important, in any part made up of two readings it can be assumed that the instrument drift error is approximately the same for each reading. In taking the difference between the readings for two objects in a part, the instrument drift, whatever in may be at that time, virtually drops out. The difference obtained is just about what it would be if there were no drift at all.

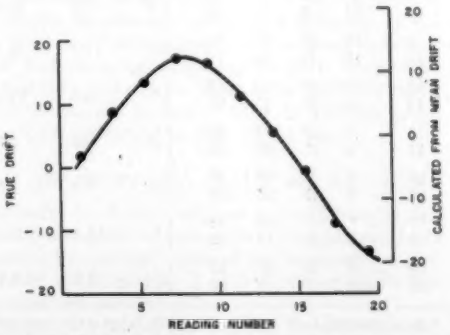

Fig. 2. Instrument drift in units of the terminal figure recorded.

Table 7. Comparison of correct and calculated values for the objects measured.

Object	Correct value	Calculated value	Calculated value less 5.0
A	75.0	79.4	74.4
B	85.0	90.4	85.4
C	65.0	70.6	65.6
D	55.0	59.0	54.0
E	45.0	50.6	45.6

The arithmetic for evaluating the objects is less involved than that used for the drift. To calculate an average for *A*, form the following differences:

Using part *a*, $A - B = -14$
Using part *g*, $A - C = 13$
Using part *j*, $A - D = 18$
Using part *d*, $A - E = 30$
Sum, $4A - (B + C + D + E) = 47$;
Equivalently, $5A - (A + B + C + D + E) = 47$;
And $A -$ average of all $= 9.4$;
Average of all 20 readings $= 70.0$; $A = 70.0 + 9.4 = 79.4$.

Table 7 shows the calculated averages for the objects alongside the correct values. There is evidently a marked discrepancy between the correct and calculated values. The fourth column shows the calculated values all diminished by 5.0, and now the two sets show good agreement. The correction, 5.0, cannot be evaluated in any actual case. It is, in fact, the average value of the drift introduced by the instrument. There is no way, short of the good fortune in having one of the objects a known standard, to separate out the average drift from the average of all the objects.

In much experimental work the *difference* between test items is all that is important to establish. Where absolute values are required, a standard object is indispensable. If the absolute value of one object is known, all other objects can then be determined.

Many choices are available in the construction of the sequence used. The parts or blocks may be of any size. For example, seven objects can be arranged in seven triads, or 10 objects in 10 triads.

ABD | BCE | CDF | DEG | EFA | FGB | GAC
ABE | HIJ | BHC | GEI | IDB | EFH | CJD | JGF | DAG | FCA

The first of these sequences is an example of a class of designs called balanced incomplete blocks. The second sequence is a partially balanced incomplete block design. Various discussions of these designs are available (*4*, *5*, *7*).

There is a final important comment to make. Comparisons of objects can be made even with a drifting instrument. Even when the instrument has been operating satisfactorily, the experimenter perforce usually has had to *assume* that this state was maintained while making the critical measurements. Statistical design makes it possible to show that the instrument did stay in adjustment and, if not, to introduce appropriate adjustments.

References and Notes

* Based on a talk given at the Gordon Research Conference on Instrumentation in 1954.
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Phase Microscopy 1950–1954

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THIS paper is an analytic summary of some 200 publications that have appeared for the most part since the publication of *Phase Microscopy* (*1*). Phase microscopy is now so generally used that it often does not appear in the titles or abstracts of papers. This makes a complete listing of papers nearly impossible, and omissions are the result of failure to find the publications. Phase microscopy is useful for the study of colorless transparent or nearly colorless transparent materials containing detail composed of small differences in optical path (refractive index × thickness).

The Phase Microscope

The principles on which the phase microscope is based are illustrated in Figs. 1, 2, and 3. On the left in Fig. 1 is shown light wave *A′* passing through a transparent object *C* and slowed down with respect to light wave *A*, which did not pass through the transparent object. Accordingly, light wave *A′* is out of phase with light wave *A*. However, both the human eye and photographic plates are insensitive to phase differences, and as a result the image can scarcely be seen or photographed. Light wave *A″* passing through an absorbing medium *E* is reduced in amplitude (dis-

tance from crest to trough of the wave). In contrast to phase differences, amplitude differences are visible. When light waves of the same phase and amplitude R are combined in the image they add up to produce brighter contrast (Fig. 1, right). Dark contrast can be achieved by producing light waves S which are out of phase or amplitude with each other. Other combinations of amplitude and phase produce lighter or darker grays.

Figure 2 shows how light waves are superimposed. Section 1 shows that the wave P resulting from a slightly retarding particle may be broken up into two waves S and D. These waves, the central wave S and the diffracted wave D, are shown again more clearly in section 2. Section 3 shows the result of using a bright contrast diffraction plate. Wave S has been partially absorbed and retarded so that S and D are in phase and combine to produce a brighter image. Section 4 shows wave S partially absorbed and wave D retarded, so that S and D are out of phase and produce a darker image.

To convert a brightfield microscope into a phase microscope, one replaces the condenser with a phase condenser containing an annulus (Fig. 3, K, L) and the objective with a phase objective containing a diffraction plate (Fig. 3). No change is required in the rest of the equipment.

When the annulus is illuminated, its image is formed at the back focal plane of the objective. A specimen placed on the microscope deviates some of the light throughout the objective. The diffraction plate is made to fit the image of the annulus in the objective by evaporating onto the diffraction plate a metal layer of proper shape and thick enough to absorb as much of the nondeviated light as desired, and by using a dielectric material (MgF_2) to retard the light, or both. These materials can cover the conjugate area of the annular image, the rest of the area (complementary area) or part of each area. The contrast depends on the nature of the diffraction plate, the width of the annulus and conjugate area, and the position of the conjugate area. A retardation by a quarter wavelength is satisfactory for many specimens. Metal layers transmitting 7 to 20 percent give high to low contrast.

A diffraction plate with the dielectric retarding material and the metal on the conjugate area weakens and retards the undeviated background light without affecting the light deviated by the specimen; with it

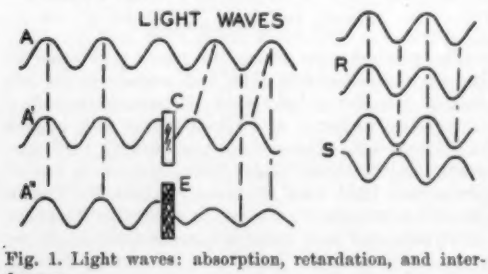

Fig. 1. Light waves: absorption, retardation, and interference.

regions of higher index in the specimen appear brighter than regions of lower index. This gives bright or negative phase contrast.

For dark, or positive, contrast the undeviated background light is absorbed by metal on the conjugate area and the deviated light from the specimen is retarded by the dielectric on the complementary area (A-type); or the undeviated light is weakened or retarded by metal and dielectric on the complementary area of the diffraction plate in the B-type of dark contrast phase microscopy.

These essentials briefly describe the ordinary phase microscope. Instead of fixed contrast diffraction plates, experimental work has been directed toward variable and color contrast. Details of construction, theory, and application are available in (*1*) and the papers mentioned in this review, which should be consulted for further information.

Theory and Instrumentation

General elementary papers have been published by Brice (*2*), Discombe (*3*), Hopkins (*4*), Hughes (*5*), Hughes and Cardew (*6*), Haselmann (*7*), Inagaki (*8*), Keuning (*9*), Lippert (*10*), Martin (*11*), and Richards (*12*). More advanced discussions include those of Berti (*13*), Françon and Saez (*14*), Royer (*15*), and Kenohane (*16*), Radojičič and Brausil (*16a*). Osterberg (*17*) includes a simplified explanation of phase microscopy and states the conditions for maximum and minimum contrast. The vector theory of phase microscopy has been elaborated by Barer (*18*) and nomenclature for phase microscopy has been proposed by Barer (*19*) and Locquin (*20*). A book has appeared in Japanese by Mizuhira (*21*). Hansen *et al.* (*22*) present briefly the theory of the phase microscope and discuss its application to medicine. Hori and Hori (*23*) describe an approximation system for phase microscopy, and Torikai (*24*) discusses image formation in phase microscopy.

The Reichert vertical illumination phase equipment has been described by Gabler (*25*) and the Reichert phase microscope by Luschin (*26*). Haselmann (*27*) has written a general article on phase microscopy and has described the Winkel-Zeiss phase equipment. Zernike (*28*) has obtained a patent for achromatic and color diffraction plates. Françon and Nomarski's vertical phase illuminator has been patented and has been described for a Nachet microscope (*29*). Other patents include a slide for phase microscopy by Bennett (*30*), a turret by Aitcheson (*31*), and vertical illumination by Osterberg and Jupnik (*32*). Harrison (*33*) has written on homemade equipment for phase microscopy. Gottschewski (*34*) has described the Leitz phase microscope with a simple annulus in the condenser that may be magnified to match the diffraction plate by focusing the condenser and which also gives darkfield illumination (*35*).

Variable phase microscopy has progressed slowly because of technical difficulties in manufacturing. Cooke, Troughton, and Simms have made two variable phase microscopes, similar to the Polanret system of

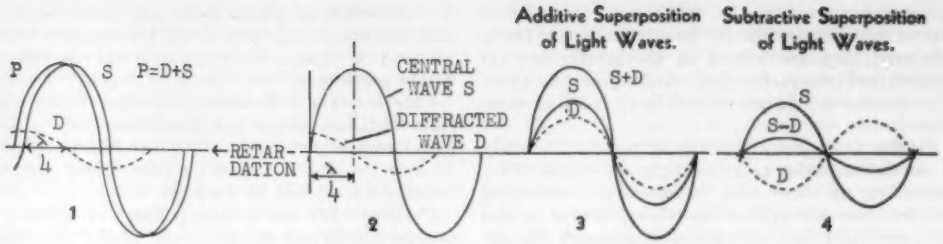

Fig. 2. Contrast control by adding or subtracting light.

Osterberg and Bennett (*36*) except that quartz was used in the diffraction plate instead of Polaroid, but they are marketing a multipupil system with variation in amplitude alone (*37*). Locquin (*38*) and Dufour and Locquin (*39*) used an interferential phase ring instead of the classical type to obtain variable contrast through varying the wavelength of the illumination; it is manufactured by the Société Wild. Variable color (Saylor's system) and comparison with Rhinebeng illumination led Gabler (*25a*) to conclude that the best system would use a dispersion medium in the phase plate. Unresolved opaque particles may be measured by phase (*40*). Patents on variable phase have been issued to Kastler and Montarnal (*41*), Françon and Normarski (*42*), Groves (*43*), Taylor (*44*), Osterberg and Bennett (*36*), and Bennett (*45*). A quartz reflecting system for colored phase contrast has been patented by Françon (*46*).

Baker (*47*) recommends that 6-μ unstained sections of snail or slug ovotestis (Zenker fixed-paraffin sectioned) be used as test material for all powers of the phase microscope. He also advises against the use of monochromatic light for phase microscopy. If a green filter is desired, he prefers the Ilford No. 803 for both daylight and tungsten light. Rind (*48*) recommends Agfa X-Ray Fluorapid Film and other European films for photomicrography.

The halos seen around starch grains and other details with the phase microscope are attributed to lens effects by Frey-Wyssling (*49*), and a later paper (*50*) indicates that the images of lenslike objects are formed of mixed brightfield and phase portions. He also notes a reversal in contrast when the index of the medium is more or less than the index of the starch. Barer (*51*) advises mounting starch in cedar oil and using polarized light (*52*). Epstein (*53*), using a point source, concludes that the edge effect is the result of diffraction, and Butterfield *et al.* (*54*) have obtained smaller halos by using unequal areas in the annulus and diffraction plate. B-type dark contrast may be preferable to A-type because of smaller halos (*55*).

Phase Combined with Other Methods of Microscopy

Barer (*56*) discusses the possibilities of infrared phase microscopy and Taylor (*57*) describes the addition of phase to the Cooke, Troughton and Simms ultraviolet microscope. Phase is preferred to darkfield for locating the region to be photographed in ultraviolet. It is possible after taking the picture to shift back to phase to determine any damage from the ultraviolet radiation. King (*58*) describes the addition of a phase searcher to the Burch reflecting microscope. Comparison of the phase and ultraviolet pictures assists interpretation of the specimen, especially in the location of nucleic acids and proteins.

The use of the phase microscope together with other methods of microscopy is now frequent and is yielding considerable information. Richter (*59*) reports using fluorescence and phase microscopy for locating carcinogens within human blood cells and chick heart cultures. Methylcholanthrene, benzpyrene and dibenz-

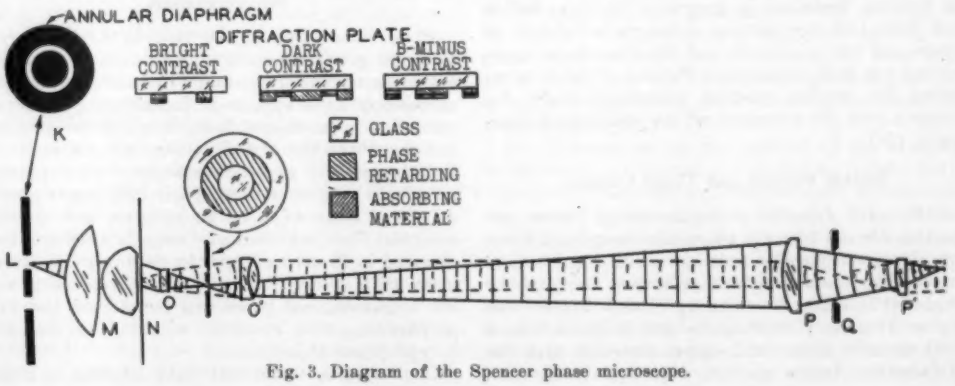

Fig. 3. Diagram of the Spencer phase microscope.

anthracene are soluble in the human and chicken plasma and concentrate in the chylomicrons. Intracellularly, they are located in the cytoplasmic fat droplets and the juxtanuclear Golgi granules. There is no fluorescent evidence of their being in the erythrocytes.

Pfeiffer (*60*) uses a Polanret system for the study of starch, combining polarized light and phase. After questioning by Barer (*61*) he admits (*60*) obtaining the idea from the work of Osterberg. Dolejsi is also using polarized light with phase microscopy. The advantages of phase microscopy with birefringent objects are pointed out by Barer (*62*) and the problems of combining phase and interference microscopy are discussed by Barer (*63*) and by Françon (*64*).

The phase and electron microscope combination is proving particularly fruitful. The phase microscope gives basic orientation and the electron microscope considerable detail (*65*). Ornstein and Polister (*66*) use thin sections for the electron microscope and slightly thicker ones (1 μ) for phase microscopy. With good fixation they find no need for staining, for phase shows adequate detail. Gey and Bang (*67*) also are using the combination to study the fibrous components of the hyaloplasm and the character of intracellular traffic in a typical and normal cell. Comparable work on bacteria is reported by Winkler *et al.* (*68*). Yamaguchi (*69*) used phase to examine the extent that replicas are faithful representations of the sources from which they are drawn. Phase and electron microscopes are elucidating the life cycle of fowl plague virus for Flewett and Challice (*70*).

The use of dispersion staining for the localization of free silica has been proposed by Crossmon (*71*). Koenig *et al.* (*72*) report photomicrographs of living cells obtained with phase and with ultraviolet microscopy. Focusing was done in visible light to minimize damage from the ultraviolet exposure. The ultraviolet pictures provide information on the morphologic distribution of nucleic acids and protein in living cells and show alternation from fixation which can be compared with the living by phase and by staining in brightfield.

Investigations using phase and electron microscopy on nervous tissue are in progress (*73, 74*). Dalton and Felix (*75*) are working in the epithelial cells of mouse and rat epididymis, and other combined applications will be described later. Phase is of aid in orientation for detailed electron microscope study, for instance with the nebenkern of the grasshopper spermatid (*76*).

Motion Pictures and Tissue Cultures

Cliffe (*77*) describes a simple motion picture apparatus for use with the phase microscope and Frederic discusses cytologic techniques with phase microscopy. The motion picture equipment designed by Michel (*78*) is manufactured by Winkel-Zeiss according to Frederic (*79*). Laporte and Roehrich-Goussu (*80*) describe zenon or krypton electronic flash for illumination. Twelve pictures were made per second with exposures of about 30 μsec (8 joules) with the 85X immersion objective. Locquin's varicolor system required 32 joules. The equipment can provide 100 flashes per second.

Chevremont and Frederic (*81*) report motion pictures of tissue culture and Haselmann (*82*) is using phase motion pictures to study the fixation process. A slide has been designed by Chevremont (*83*) for tissue culture phase microscopy.

Pomerat (*84*) has motion pictures of cultures of skeletal muscle and nervous tissue. Ruffled membranes were seen in cultures of cat nervous tissue along the course of the cell processes, and they postulate that perhaps *in vivo* similar activities may obtain and assist in the propulsion of interstitial fluid in brain tissue. Rhythmic pulsations have been observed by time-lapse motion pictures on the oligodendrologic cells from the corpus collosum of the rat and cat, as well as the human cerebral cortex. Rotation of the nuclei of human nasal mucosa is shown by motion pictures of the cultures (*85*).

Richter (*59*) has filmed the reactions between leucocytes and crystalline methylcholanthrene, and Policard and Collet (*86*) report a motion picture showing the phagocytic reaction to quartz and carbon particles. Besis and Bricka (*87*) and Blandau *et al.* (*88*) use phase motion pictures to study blood cells. Pseudopod formation in phagocytosis is described briefly by Frederic and Robineau (*89*). Lettré pictures fibroblasts with phase and with Ehrlich-Bondi stain (*89a*).

Lumsden and Pomerat (*55*) report the B-type dark contrast preferable to the A-type dark contrast for photography of tissue cultures because less detail is obscured by halos. Phase pictures of fibroblasts growing in an air bubble have been obtained with dark contrast phase by Slabeycius and Fisher (*90*) with a combination of Carrel and Lewis techniques for tissue culture. The effects of beryllium on the mitotic growth of tissue cultures have been examined by Chevremont and Firket (*91*). Applications of phase microscopy in tissue culture are summarized by Richards (*92*). The culture chamber of Christiansen *et al.* (*93*) should be useful in phase microscopy.

Microorganisms

Phase microscopy as reported by Linhardt (*94*) shows the gelatinous material in blue-green algae without reagents. Numerous studies of bacteria with phase microscopy have appeared. Techniques for the examination of unstained living bacteria are summarized by Poetschke and Bommer (*95*). A series by Delamanter (*96*) and his associates (*97*) suggests a mitotic division in bacteria. Their 1952 paper gives a review of their work on *T. pallidum* and *Borrelia anserina*. The formation of "large bodies" has been observed in *Proteus vulgaris* by Stempen and Hutchinson (*98*). Many of their pictures were made with low bright contrast phase and the stained and fixed preparations were examined with the medium dark A-type phase objectives.

Doglioni (*99*) found that many cells can be identi-

fied in sputum with phase microscopy. Cultures of avian tubercle bacilli show long filamentous mycelia, branches of which develop into long strands of bacilli. All observed types of growth resulted in the ultimate formation of acid-fast bacteria (*100*). Phase microscopy is reported to be about twice as good as bright-field for finding tuberculosis bacteria in some 2028 examinations of sputum, stomach washings, and so forth, by Poetschke *et al.* (*101*). Unstained tuberculosis bacteria are examined in phase and darkfield by Kolbel (*102*) to avoid the shrinking, coagulation, and destruction of the staining procedures, and Tokiwa (*103*) believes he has seen budding from a refractile body formed at one end of the tubercle bacillus.

Morphologic changes to penicillin in *P. vulgaris*, *E. coli* and *B. anthraxis* have been observed by Levaditi *et al.* (*104*) and Eisenstark *et al.* (*105*) have used phase and electron microscopy in the study of a pleomorphic strain of *Azotobacter*. Héden (*106*) used phase and a special chamber to mount *E. coli* with the phase microscope.

Phase microscopy proved helpful to Browning *et al.* (*107*) for the examination and timing of nuclear cytoplasmic and cortical divisions of *Tetrahymena*, and inclusions were studied by him (*108*) in colonies of the organism mounted in immersion oil.

Cells and Tissues

Passano (*109*) used phase for examining teased, living cell bodies from the crab *Sesarma*. The cells, from the organ forming the molt-inhibiting eye stock hormone, resemble steroid systems similar to the Golgi apparatus of Baker and Thomas. Good bright contrast phase pictures of mitochondria in the flight muscles of insects have been published by Watanabe and Williams (*110*). The association of mitochondria and the Golgi net is discussed by Taylor and Adamstone (*111*). After comparing phase with hematoxylin-eosin stained sections, Kludas and Maibauer (*112*) conclude that in many cases, but not all, phase reveals more structural detail, but they advise further comparison.

The refractive index of living cells has been obtained by Barer and Ross (*113*) and Crossmon (*114*) by immersing them in known solutions, for example bovine plasma albumen, and matching under the phase microscope. By combining this technique with the use of interference microscope, they claim that the total dry weight, the concentration of solids and water, and the cell thickness and volume can be determined. Methods for studying the third dimension of cells and tissues including the use of phase and interference microscopy have been summarized by Richards (*115*). Interference is useful also for the study of thickness, surface effects, and phase for making stereophotomicrographs. Changing contrast by varying the refractive index of the mounting fluid has been rediscovered by Hirsch (*116*). Refractive index data for some mounting mediums are given by Lillie (*116a*).

Further work on the effects of killing and fixing fluids has been reported. Rather and Brice (*117*) recommend Goucher cells from impression preparations of spleen for this work and report comparison with phase on unstained, and after hematoxylin and eosin staining. The effects of formaldehyde fixation have been analyzed by Crawford and Barer (*118*). Haselmann (*82*) has studied structural changes, using a circulation cell for tissues, and measuring area changes with a planimeter to assess shrinkage.

Policard *et al.* (*119*) have examined a number of fixing fluids, and conclude that osmic acid is the best because it causes no distortion other than slight shrinkage of the nucleolus with polymorphonuclear and thrombocytic cells. Other fixing fluids gave a mediocre result on nuclear sap, coagulating it in large masses, except bichloride of mercury and potassium bichromate which produced a fine reticulum. With these compounds the cytoplasm appeared well enough fixed. Almost all the fixatives thickened the cell membrane. Freeze-drying is useful but needs improving.

The phase microscope is being used to study the effects of various physiological agents. For instance, phase photographs have been made of cells of rabbit ovarian granulosa cultivated after having been cooled to a very low temperature (*120*). Phase microscopy has been applied to the Sabin-Feldman reaction by Lelong and Desmets (*121*), and to the Gomori reaction by Hancox and Nicholas (*122*). Zollinger (*122a*) discusses intravital phase microscopy.

The effects of a microbeam of protons on dividing cells are photographed in motion pictures by Bloom and Zirkle (*123*). Pomerat (*84*) describes a chamber for continuous perfusion of cells for environmental studies.

Giant chromosomes swollen in 0.14*M* sodium chloride have been examined by Ambrose and Gopal-Ayengar (*124*) with phase microscopy and by birefringence with a microscope arranged as a flicker dichroscope. An orientation of large molecules within the chromosome is indicated. Dennes (*125*) disrupted chromosome fragments from chicken erythrocytes with a Waring Blendor for comparative pictures with phase and electron microscopes.

Tahmisian and Adamson (*126*) saw the chromatin in the resting grasshopper nucleus mounted in Belar's solution with dark medium phase. Pyenosis from x-ray effects appeared as a diminution of the viscosity in the nucleus. The effects can be delayed by placing the grasshopper embryos in cold storage, but when they are brought back to 25°C, pyenosis occurs. Roto-oscillating motions of the chromosomes were found in grasshopper eggs (*76*, *127*).

New information on the surfaces of the bile-conducting cells in mammals is reported by Ralph (*128*). Thin 1-μ sections were used without stain, and contrast was varied by changing the refractive index of the mounting mediums. Evidence of spiral internal surface sculpturing was seen in the walls of the bile capillaries, and filamentous structures were seen on the interlobular bile ducts, hepatic cells, gall bladders, cystic ducts, and common bile ducts. Size and number varied in different species. Liver cells show nuclear walls with B-type contrast, Golgi apparatus with low

A-type contrast and mitochondria with medium A-type contrast using a Tiyoda Phase Microscope (*23, 129*).

Morris (*130*) reports that the phase microscope is satisfactory for the examination and evaluation of bull semen without fixing and staining, and Fossel (*131*) recommends the phase microscope for evaluation of spermatozoa. By varying the refractive index of the mounting medium, Blandau (*132*) saw more detail in rat spermatozoa taken from the epididymis than with previous methods. The perforatorium divides into two prongs which fit neatly along the rostral-ventral part of the elongated nucleus, and the axial filament was observed to be composed of 7 to 9 continuous fibrils that extend throughout the middle piece and tail. The fate of these parts in fertilization is being investigated.

The detailed description of the rat's spermatid is given by Austin and Sapsford (*133*) from preparations obtained by wiping a slide onto a cut surface of testis or from a bit of the macerated tissue. Van Duijn (*134*) has published a detailed description of the human spermatozoon from study with special differential stains, darkfield, phase, and fluorescence microscopy. Pictures of spermatogenesis in the grasshopper are published by Cleveland and Winchester (*135*), and by Winchester (*136*).

A slide with an aluminum spacer has been described by Smith (*137*) for culturing rabbit eggs for examination with the phase microscope. The phase and ultraviolet microscope were used by Austin (*138*) to determine the location of nucleic acids within the nuclei of living segmented rat eggs. Time relations and form changes of fertilization and first segmentation division in rat ova have been described by Odor and Blandel (*139*).

Incinerated blood cells examined by Kruczynski (*140*) revealed less potassium and iron in senile cells than in cells from younger individuals, although analyses showed considerable variation. Cellular and nuclear membranes leave mineral deposits composed of calcium and perhaps phosphorus.

Considerable interest has been shown in the counting of platelets by phase microscopy. Cazal and Izarn (*141*) recommend phase for counting of both platelets and reticulocytes. Brecher *et al.* (*142*) find that "Phase is the easy and certain recognition of individual platelets, and it is believed that this accounts for a satisfactory reproducibility even by inexperienced technicians." They use a diluting fluid without cocaine, and their work has been summarized (*143*). Zuckor (*144*) has used the phase microscope to study and classify platelets which vary in shape from smooth disks to others with spiny projections.

Weis-Fogh (*145*) has described a flicker phenomenon, or change of optical density, in erythrocytes which was thought to be a possible test for activity. A further study by Parpart *et al.* (*146*) showed that it could be seen with a change of mediums and in hemolyzed cells, and concluded it is not related to metabolism but to the Brownian movement of the cell. Tompkins (*147*) reports that the internal movements of the erythrocytes are lost in saline washed cells, but return when the cells are returned to the serum.

The movement of leucocytes is being investigated by Neuman and Kreis (*148*) and phase is recommended by Crossmon (*149*) for counting white blood cells. Phase microscopy is used by Shelton *et al.* (*150*) for counting mitochondria, and they include formulas for estimating errors. The storage of hemoglobin in kidney cells after intraperitoneal injections of hemolyzed blood has been examined with phase by Zingg and Zollinger (*151*).

Bright contrast phase shows hyaline membranes and amyloid deposits at the capillary wall and the intercapillary space of kidney glomeruli (*152*). The structure of skin and the detail of the sweat glands is described by Takagi (*153*) who used phase microscopy and fresh material. The lumen of the duct was found to be lined with epithelial cells throughout its length.

The transparent tissues of the eye can be examined to advantage with phase. François and Rabaey (*154*) find that epithelial cells of cataractous human lenses appear differently from those of normal lenses in vacuolation and pigment changes. No inclusion bodies were seen, although the normal structure was clearly seen in the cellular elements of the conjunctiva and corneal epithelium in epidemic keratoconjunctivitis (*154a*). The endothelium of the cornea is composed of large cells with 2 nuclei each and a granular cytoplasm. The structure of the cornea after the epithelium was removed is illustrated by a replica. Yamamoto (*155*) saw a membrane in unstained rabbit cornea resembling Boman's membrane. Böke has studied the lens epithelium (*156*).

Asayama and Nakashima (*157*) show stellate cells in the normal capsule and in cataract they found perinuclear vessicles.

The vitreous body shows definite fiber structure under the phase microscope. Bembridge (*158*), Swartz and Schuchardt (*159*), Grignolo (*160*) and Richards (*161*) have published pictures showing structure. Swartz and Schuchardt used phase and darkfield and an immersion ultramicroscope in their study. Grignolo shows that the fibers split into progressively smaller elements which anastomose to form a fairly extensive network posterior to the equator. In man, this is connected anteriorly with fibrous bundles that are firmly attached to the vitreous base. The vitreous is limited by a homogeneous membranelike transparent layer. Rossi fails to find fibers in very fresh rabbit vitreous and believes the fibers are formed postmortem (*162*).

An examination of a sympathetic ganglion with Sudan black and with phase led Gatenby and Moussa (*163*) to conclude that Baker and Owen were wrong with regard to the Golgi apparatus. Cole (*164*) has some pictures and comments on the study of rabbit muscle cells. In the mouse the Golgi apparatus is characteristically wrapped around the nucleus, but as the mouse ages, it breaks away from the nucleus. Green (*165*) found a copious innervation in the adenohypophysis of man and the rabbit using a controlled phase

and impregnation technique. Höpker (*166*) believes the "inner body" to be a physical product of the nucleolus. He used phase microscopy and a series of mammalian brains. Globules and filaments are found in brain tissue from mentally sick people and Papez (*167*) reports a life cycle for these "organisms."

Owen's lines of dentine and Retzius streaks in the enamel of the tooth have been observed with the phase microscope in 80- to 300-μ sections of tooth by Bodingbauer (*168*), and Gustafson (*169*) has made a detailed study of the structure of human dental enamel by means of incident light, polarized light, phase microscopy and micro-hardness tests. The epithelium around the teeth of vitamin-A deficient rats shows aplasia of the basement membrane, degeneration of the tonofibrils and parakeratosis of the surface layer according to Baum and Frandsen (*170*). A study of replicas from tooth surfaces by phase microscopy led Frank (*171*) to conclude that the initial step in caries is proteolysis. A fine cell structure in the organ of Corti is described by Katsuki and Covell (*172*).

Medical

The use of the phase microscope is gaining in the medical profession. Hansen *et al.* (*22*) and Matilla *et al.* (*173*) summarize the main applications as follows: (i) clinical analysis of urine sediments, vaginal exudates, feces, semen, sputum, cerebrospinal fluid, blood cells, and red, white, reticulocyte and platelet cell counts; (ii) protozoology for cysts and active animals; (iii) bacteriology for unstained, living organisms, agglutination, virus and inclusion bodies; (iv) helminthology, identification of eggs and diagnostic details of adults; (v) biopsy specimens, especially bone marrow and spleen; (vi) identification of fungi and fungus infections; (vii) normal and pathological histology, tumor diagnosis, phagocytosis, transplantation and regeneration; and (viii) measurement of unstained, living microorganisms.

Discombe (*174*) states that the diagnosis of leukemia can sometimes be made more rapidly with the phase microscope. Mizuhira (*175, 176*) discusses the advantages of phase for the examination of connective tissue and the arrangement of the fibers within it. Merklen and Cottenot (*177*) recommend phase microscopy for venereal dermatology. Other articles in this field are by Bommer (*178*), Brodskii (*179*), Fritze and Streufe (*180*), Kostic (*181*), Mannigault (*182*), and Pulvertaft (*183*). Lash and Antonow discuss cervical and endometrial carcinoma (*184*).

Phase motion pictures of a chemically induced rat tumor tissue show living leucocytes *within* the tumor cells (*185*). Seyfarth (*186*) suggests that the small granules in tumor cells are endospores, from which microorganisms develop. Ludford and Smiles (*187*) report on a malignant cell polymorphism. The phase microscope shows a canalicular system which enlarges in the giant cells to fill all but a small ectoplasm. The cytoplasm changes during mitosis with disorganization of the canalicular system, but remnants persist as vacuoles.

Martinez (*188*) concludes from a study of eight gliomas with H and E, and with silver staining and with phase that the phase microscope gives the same diagnosis more quickly and more easily than the classical methods. Staining methods also were reported cumbersome, damaging to tissue and time consuming, as compared with phase microscopy by Siering (*189*). Tumor cytology is the subject of a paper by Adehold and Siering (*190*) and ascites tumors are examined by Makino and Nakahara (*191*). Tumor diagnosis can be made from renal cells in the urine when biopsy is impractical (*192*).

Policard and Collet (*86*) call attention to the advantages of phase motion pictures for the study of phagocytosis with respect to pneumoconiosis.

Industrial

Phase microscopy has been reported by Camus *et al.* (*193*) as useful for the examination and evaluation of ghosts in gratings. Graininess in photographic emulsions has been examined by Falla (*194*); particle sizes of 0.1 to 0.4 μ were estimated with the phase microscope from the color of the photographic emulsion. A paper in Japanese by Tajima, Yamaguchi, and Hosoya (*195*) includes pictures of a number of photographic emulsions.

Seidenberg and Benford (*196*) describe the addition of a phase system to the Bausch & Lomb Metallograph and the advantage it gives in showing more detail, particularly of pearlite, stainless steel and Monel. The Reichert metallographic phase microscope is described by Gabler (*25*). Greater useful contrast occurs with particles in steel, chalcopyrite, coal, ores and refractories when examined with phase vertical illumination (*197*). Perryman and Vernon-Smith (*198*) are investigating the correlation of observations of metal surfaces with light and electron microscopes. Kehl (*199*) reports that phase microscopy is helpful in revealing prices and boundaries on metal surfaces.

The darkfield produced with a too large annulus image of the phase microscope is used by Yamaguchi (*200*) to examine the sharpness of razor blades. Crossmon (*71*) finds that phase microscopy is useful for the identification and counting of dust particles.

A brief summary of the possibilities of phase microscopy in the brewing industry was published by Richards (*201*).

Horst (*202*) discusses the study of coal. Replicas were made with glycerine jelly, and photomicrographs show algae, pollens, *Sclerotium*, and megaspores and microspores of *Triletes*. The article discusses the application of phase to the study of coal bogs.

The surface membrane was removed from wool fiber by Mariner (*203*) and studied with phase and polarization microscopy. With phase they could see a differentiation of intensities representing 300 to 400 A. In a summary of the proceedings of the conference on optical and electron microscopical properties of textile fibers, Drummond (*204*) discusses the use of different kinds of microscopes indicating that polarized phase is useful with viscose cross sections.

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Hydraulic-Leverage Principles for Magnification of Sensitivity of Gas Change in Free and Fixed-Volume Manometry

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BIOCHEMICAL, biophysical, and other users of conventional types of manometers have often wished to measure volumes of gas changes with a sensitivity far greater than the commonly obtained order of a cubic millimeter, without having to resort to extensive changes in apparatus, to microscope cathetometers, or to esoteric instrumentation. Small sensitivity gains up to onefold or so have indeed been attained with conventional manometers by the use of tilted manometer arms, confining fluids of low-weight density (for example, hydrocarbons or oils of $D \sim 0.7$ g/cm³), small experimental vessels, or, what comes to the same, vessels filled with relatively large volumes of liquid.

This paper shows how, with or without the aforementioned minor devices, additional sensitivity gains of 10- to 100-fold may readily be achieved with little or no change in widely available commercial manometers by appropriate use of hydraulic-leverage principles (amplification by fluid geometry rearrangement) combined with unusual moving-boundary indices. The procedures to be described are remarkably simple in both theory and practice and may be applied to both constant-(fixed) volume manometry and free manometry (volume and pressure variable), including volumetry. The open-arm, fixed-volume manometer made classic and universal by Otto Warburg (*1–5*) is chosen to provide a basis for illustrating the application of the hydraulic-leverage principles involved and to provide an arbitrary standard of reference by which to judge the sensitivity magnification obtained. Applications to a wide range of manometer types will be readily evident, including differential and compensation manometers and Cartesian diver techniques (*6–8*). Finally, several new types of hydraulic manometers are described, including a general-purpose manometer and a one-arm free manometer of unique advantages in which paradoxically an increase in the amount of confined gas results in a decrease in pressure of the gas (*sic!*).

In the Warburg manometer (Fig. 1) a change in amount, x (mm³) N.T.P., of a given gas in the reaction vessel is equal to hk, where h (mm) is the resulting, experimentally observed, vertical displacement of the meniscus of the fluid in the manometer arm open to the atmosphere when the meniscus of the confining fluid in the closed arm is maintained at a fixed level (by means of the adjustable screw and fluid-filled sac at the base of the manometer), and k (mm²) is the standard vessel constant parameter $[(v_G \cdot 273/T) + v_F\alpha]/P_o$, v_G (mm³) being the volume of gas space in the vessel to the level of the confining fluid in the closed arm, v_F the volume of liquid in the vessel itself, α the Bunsen absorption coefficient of the given gas in the liquid in the vessel, T the average absolute temperature of the confined gas, and P_o the pressure of 1 atm expressed in millimeters of confining fluid (for example, 10,000 mm Brodie's fluid of weight density $D = 1.034$ g/cm³, equivalent to 760 mm-Hg of weight density $D = 13.60$ g/cm³).

In the standard arrangement for operating the Warburg manometer, h (mm) of confining fluid is a measure of the change in pressure Δp induced by a change of x (mm³) gas kept at constant volume and other conditions implied in the formula just given for k. In the hydraulic-leverage arrangement described here, for given values of x and k, h is further magnified to a larger value H, with a corresponding and reciprocally decreased smaller value of K, such that $x = hk = HK$. The theoretical sensitivity magnification may then be defined as $M = H/h = k/K$, so that $H = hM$ and $K = k/M$. M thus defined is, for constant-volume manometry, independent of the attributes and events of the manometer vessel (v_G, v_F, α, T, P_o, x) and depends in principle only upon the leverage events and arrangements in the manometer measuring arms (*9*). In this last connection it is important to observe that the upper end of the open manometer arm of virtually all present-day commercial Warburg manometers consists of, or may be readily made to hold, a wide and even-bore *reservoir* 30 to 40 mm long, whose area A (30 to 50 mm²) is some 10 to 100 times the area a (0.5 to 3 mm²) of the narrow, even-bore capillary with which it is contiguous below (corresponding ratio of radii, $R/r \cong 3$ to 10).

Sensitivity magnification with constant-volume manometry. To set up the desired hydraulic-leverage arrangement, two operations, each requiring a few seconds, must be carried out: (i) the upper level of the manometer fluid in the open arm is raised from its normal position in the capillary into the even-bore section of the reservoir and maintained there throughout the experiment; and (ii) a bubble of room air (or bubble of any suitable and convenient gas or im-

miscible liquid) of length slightly greater than the diameter of the arm capillary, is inserted into the fluid in this capillary by means of a long and narrow needle attached to a syringe or medicine dropper bulb (Fig. 2). Short of gross mishandling, the static position of the bubble in the capillary fluid is indefinitely stable in accordance with the IXth Hydrostatical Paradox of Robert Boyle. Such a bubble moves freely and reversibly in response to changes in Δp or to turning of the adjustable screw pressing on the sac at the base of the manometer. The movement of the bubble is an accurate measure of both the volume and distance displacements of the confining fluid in the capillary.

Any change in height h $(=\Delta p)$ of the air-fluid interface meniscus in the reservoir taking place as a result of change x of gas in the experimental vessel held at constant volume and temperature will be magnified A/a times in the movement H of the bubble-fluid interface in the capillary below, for the *volumes* of fluid displaced in the capillary and in the reservoir must obviously be identical. Hence $M = A/a$; $h(=\Delta p) = Ha/A$; $H = \Delta pA/a = hA/a = hM$; and $K = ka/A = k/M$.

To calculate x by the proposed reservoir-bubble leverage arrangement, one merely multiplies the observed displacement H by K, that is, $x(=hk) = Hka/A = HK$. Although a and A may be determined separately by mercury calibration in the usual manner, only the ratio a/A need actually be known for the purpose indicated. The ratio a/A may be ascertained most directly, and in the course of only a few seconds, by measuring the ratio of height change in the bubble level in the capillary compared with that of the air-fluid level in the reservoir when both levels are altered simultaneously by turning the adjustable screw, preferably over as wide a range as possible, or by particular parts if need be. Such a determination of a/A can obviously be carried out completely independently of any attributes of, or events occurring in, the other manometer arm or the reaction vessel—even during an experiment if need be—and indeed may be determined in the complete absence of the other arm and vessel if one employs the original Barcroft-Haldane form of Warburg manometer constructed with separable arms (Fig. 3) (*10–12*).

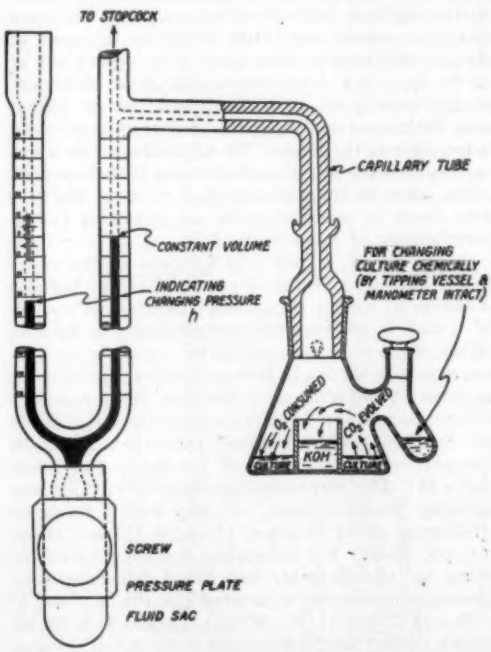

Fig. 1. Typical Warburg manometer and illustrative vessel, arranged for operation at constant volume of gas space; x (mm³) N.T.P. gas change $= hk$, where $k = (v_g \cdot 273/T + v_f\alpha)/P_o$.

The increased sensitivity of the reservoir-bubble leverage arrangement calls for adequate thermobarometric control in order to achieve full theoretical sensitivity magnification in practice, with minimization of "noise." Especially with extreme values of magnification M it may be desirable, just as in conventional manometry, to connect the open ends of the manometer arms of the thermobarometer and all experimental vessels via a manifold with pressure tubing or plastic connections to a single 1- or 2-lit flask filled with water-vapor saturated air and immersed in the thermostat bath in order to eliminate sudden large or variable atmospheric pressure changes that may occur in some laboratories. In any event the thermobarometer H correction must, at least where large, first be multiplied by its relative a/A value with respect to the a/A value of each experimental vessel, for H values obtained by the reservoir-bubble arrangement are not equal to, but only proportional to, h and Δp values, the proportionality constant being A/a. For this reason, when manometers on hand are significantly variable with respect to their a/A values, it is desirable to choose for a thermobarometer a manometer whose a/A value is mean or modal.

Although there is no theoretical limit to M short of infinity, the chief practical limitation is set by the closeness with which the meniscus of the inner-arm confining fluid can be brought each time to the same constant-volume level. For conventional level setting by hand and eye (with or without hand lens), the effective limit of M is reached at values of ~ 15 to 30, depending upon the manometric fluid employed, cleanliness of the arm's inner glass wall, setting speed required, replication of settings permissible, and so forth. To obtain practicable M values above this limit, it is necessary to set the closed-arm confining-fluid level with the aid of optical, electric, or other devices. One such device is the adjustable screw at the base of the manometer, which can be used as an approximating vernier; the angular turn of the screw may be calibrated, with a suitable scale, against the fluid movement in the outer arm, and then be employed to compensate for the latter movement, by a series of approximations if necessary.

It may well be that M values somewhat less than those provided by the a/A values of manometers on hand will be desired, especially where a is very small ($r = 0.4$ to 0.2 mm for $R = 3$ to 5 mm). Such intermediate magnification, or in effect "demagnification," can be attained and regulated at will by the use of glass rods of known cross section appropriately suspended into the fluid in the open-arm reservoirs, with consequent decrease in effective A values and, hence, a/A values. Capillarity considerations here, as throughout this paper, offer no problem, since only changes in capillarity dependent on x would be involved and these are, or should be, zero.

Sensitivity magnification and demagnification can also be regulated conveniently by appropriate use of a second manometer fluid of density d, smaller than the density D of the main manometer fluid. The lighter fluid, immiscible with the denser and preferably nonvolatile, nontoxic, and odorless, is floated on top of the denser fluid in the capillary of the open arm up into the even-bore section of the reservoir. The change in height H' of the boundary between the two fluids is now observed instead of H of the bubble employed before. In this two-fluid method, Δp, for given values of x and k, is no longer equal to the change in height of the fluid in the reservoir but is given by $\Delta p = H'D - H'd + H'(a/A)d = H'[D - d(1 - a/A)]$. From this, and the fact that correspondingly in the one-fluid method $\Delta p = hD$, it can readily be shown that for $x = hk = HK = H'K'$, $K' = k[D - d(1 - a/A)]/D$, and $M = k/K' = D/[D - d(1 - a/A)]$.

Thus M increases, not only as a/A decreases, but also as $(D - d)$ decreases. In the limit of $d = D$, $K' = K = ka/A$, as with the bubble method before, so that, whether one employs the bubble method with one fluid or the boundary method with two different fluids of equal density, the theoretical result of complete dominance of sensitivity magnification by a/A remains the same. In the limit of $d = 0$, $M = 1$, which must be true since there is then no liquid in the reservoir. In the limit of $a = A$, $M = 1$ also, and there is likewise no sensitivity magnification, because the diameters of the capillary and the reservoir are the same, and a difference between a and A is a *sine qua non* for sensitivity magnification of $M > 1$, regardless of any relationship D/d.

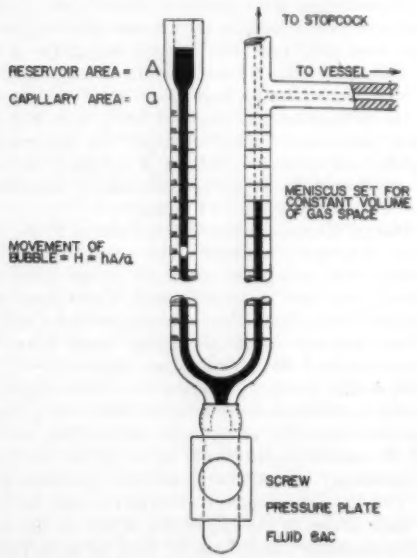

Fig. 2. Warburg manometer arms with reservoir-bubble arrangement for hydraulic magnification of sensitivity at constant volume of gas space: x N.T.P. gas change $= hk = Hk \cdot a/A = HK$, where $K = ka/A$, and the sensitivity magnification $M = H/h = A/a = k/K$.

Finally, in the limit of a/A approaching zero (attained by either decreasing a or increasing A indefinitely), M approaches $D/(D - d)$. This is important because it indicates that with even reasonably small values of a/A (0.05, 0.02, 0.01), sensitivity magnification can also be regulated in a quite practical way, over a very wide range, virtually by density difference alone. Thus, if $d = 0.99D$ (which is easy to arrange, experience shows), then $M \cong 100$; if $d = 0.9D$ (as with Brodie solution-isocaproic acid combination), then $M \cong 10$; and if $d = 0.66D$ (as with Brodie solution-hydrocarbon combination), then $M \cong 3$, the exact M values being determinable in any event by the empirical method indicated earlier for the bubble method.

Sensitivity in conventional free manometry (equal capillary areas, no reservoir bubble). In conventional free manometry with the Warburg-type manometer, the confining fluid in the closed arm is not maintained at a constant level but is allowed to move freely against constant external pressure, atmospheric or otherwise. The volumes of manometric fluid displaced in the capillary sections of the open and the closed arms are exactly equal. The respective distances of fluid displacement are also equal if the areas a and a^* of the open- and closed-arm capillaries are also equal, as they usually are, to a close approximation (otherwise the respective heights would obviously be in inverse ratio as the areas). The adjustable screw below the capillaries is left untouched throughout the experiment, often in its most extended position, where it then exerts no pressure on the sac containing the reserve supply of confining fluid.

A change of x (mm³) N.T.P. gas in the vessel causes not only a change of gas pressure Δp^* but also a change of volume of confined gas space ah^*, where h^* (mm) is the displacement of confining fluid in either of the equal-arm capillaries. Owing to the gas-space volume change in free manometry, Δp^* is never as great as, and often much less than, Δp in constant-volume manometry, for given values of x and k. When the fluid movement is confined, conventionally, to the (equal) capillary sections of the manometer arms, $\Delta p^* = 2h^*$. The corresponding conventional free manometry "vessel constant," k^*, may readily be shown [following partly Warburg (*1*, pp. 9–12) and Dixon (*3*, pp. 26–32) but necessarily deviating therefrom when Δp^* of free rather than ΔP of differential compensation manometry is involved (*13*)] to be $k^* = x/h^* = 2k + (a \cdot 273/T')[(P + 2h^*)/P_o]$, where T' is the absolute (room) temperature and P the initial pressure of dry gas confined in the closed-arm capillary just above the manometric fluid level; P is as a rule so nearly equal to P_o and the term $2h^*$ so small compared with P and P_o that the expression in brackets may

be neglected with usually much less than 1-percent change in the calculated value of k^*, so that the vessel constant normally employed reduces to simply $k^* \cong 2k + (a \cdot 273/T')$.

Since k^* thus always exceeds $2k$ (by the quantity $a \cdot 273/T'$) and $hk = h^*k^*$, $2h^*$ is thus always less than h, and $\Delta p = 2h^*$ is always less than $\Delta p = h$. This means that in conventional free manometry (that is, without adjuvant use of the reservoir-bubble arrangement) there is usually a considerable loss or demagnification of sensitivity as compared with constant-volume manometry carried out under otherwise identical conditions, the more so when a is made large compared with k; a and k are commonly of the order of 1 mm² each, so that frequently $k^* \cong 3k$ and therefore $h^*/h \cong \frac{1}{3}$, and then if one reads one manometer arm capillary only, the sensitivity in conventional free manometry, as judged by the observed fluid displacement per change in amount of gas, h/x, will be $\sim \frac{1}{3}$ as great as in conventional constant-volume manometry, for given values of x and k, and if one reads both arms, 2/3 as great. Frequently employed values of a and k different from 1 mm² could obviously readily make the respective values $\frac{1}{3}$ and 2/3 either much smaller or somewhat greater but obviously never greater than $\frac{1}{2}$ and 1 as respective maximum limits. To obtain these limits of maximum sensitivity, a must be made very small compared with k, so that $k^* \cong 2k$, and $\Delta p^* \cong \Delta p$, and therefore $2h^* \cong h$. Since values of a as small as 0.05 mm² (capillary diameter ~ 0.25 mm) are feasible of construction and workable in laboratory practice, k^* can thus be made to equal $2k$ within a few percent, and similarly $2h^* \cong h$.

The usually considerable decrease in sensitivity in conventional free manometry, which has always been qualitatively evident to the bench experimentalist even without the algebraic working out of the simple vessel constant k^* given in the preceding paragraphs, is the chief reason why free manometry has so seldom been employed and indeed rarely been taken cognizance of without unnecessarily complicated formulation (*14, 15*). Nevertheless, free manometry possesses several very definite advantages not possessed by constant-volume manometry that would be highly desirable to retain if possible. Frequent resetting of the closed-arm fluid to constant level—with attendant error, uncertainty, inconvenience, and time requirement—is no longer required in free manometry, and a given experimental observation requires a single reading taken on one arm only. Free manometry thus lends itself much better to automatic and continuous recording [long a desired but seldom attained object in constant-volume manometry (*16*)] and also to following time courses of rapid reactions (*17, 18*) without the disturbance of leveling adjustments. It is worth while, therefore, to examine whether simple hydraulic-leverage arrangements may be devised for free manometry that will overcome the disadvantage of usual lowered sensitivity and yet retain the other marked advantages.

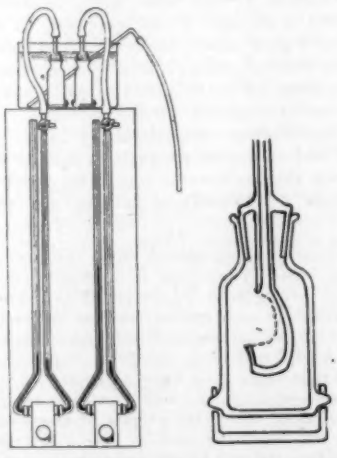

Fig. 3. The historic (1902) Barcroft-Haldane manometer and vessel type (*10*).

Free manometry with equal capillaries and open-arm reservoir. If to conventional free manometry with equal capillaries is added the open-arm reservoir-bubble arrangement described earlier in connection with constant-volume manometry, then the fluid-volume displacements are equal not only in the capillary sections of each arm but also in the reservoir, whereas the fluid-distance displacements will vary inversely with the area a of the capillaries and the area A of the reservoir. For given values of a, x, and k the fluid-distance displacements in the capillary sections will be greater than those obtained in conventional free manometry without the employment of the reservoir, by, as shown here, a maximum limit of twofold, and therefore likewise (as indicated in the preceding section) twofold the sensitivity obtained in conventional constant-volume manometry. The mathematical formulation with the open-arm reservoir arrangement is similar to that given in the preceding section for the case without the reservoir, with substitution of H^*, K^*, and A for h^*, k^*, and a (H^*, like h^*, referring to the equal fluid-distance displacements obtained in either the closed- or the open-arm capillary, being observed in the latter instance by means of the bubble movement). The pressure change ΔP^* no longer equals $2h^*$ but now equals $H^*(1 + a/A)$, whence $K^* = x/H^* = k(1 + a/A) + (a \cdot 273/T') \{[P + H^*(1 + a/A)]/P_o\} \cong k(1 + a/A) + a \cdot 273/T'$. When a/A is very small, $K^* \cong k + a \cdot 273/T'$, and, when a itself is very small compared with k, then $K^* \cong k$. This means that in free manometry with adjuvant use of the open-arm reservoir-bubble system the sensitivity, as judged by total fluid displacement per x change in amount of gas, can be made to approach as a maximum limit *twice* that obtained in constant-volume manometry ($K^* \cong k$, $K^*H^* = kh$, $2H^* = 2h$), if one reads both arms (bubble displacement in the open arm and gas-fluid interface displacement in the closed arm), just as one reads two arms in constant volume manometry. On the other hand, reading the closed arm only, the sensitivity of free manometry

with the reservoir approaches as a maximum limit the sensitivity of the constant-volume manometer ($H^* \cong h$). Experience shows that both of these manometric procedures (use of open-arm reservoir, with or without bubble) represent very practical types of free manometry that can satisfactorily replace conventional constant-volume manometry without any constructional change in widely available manometers, without disadvantage with respect to order of sensitivity (in fact with some real gain if the open-arm bubble is also observed), and with retention of the afore-mentioned advantages of free manometry over constant-volume manometry!

The open-arm reservoir-bubble procedure with equal capillary free manometry still fails, however, to produce the great gains in sensitivity magnification M that have been shown to be possible when applied to constant-volume manometry. To accomplish this, several hydraulic-leverage arrangements are proposed, all of which require small modifications in the standard Warburg manometer. The modifications may, as one chooses, be temporary or permanent, and laboratory- or commercially-made. The sensitivity magnification obtained will be intermediate (up to one order) or high (beyond one order) depending upon whether, respectively, different-sized capillaries or two reservoirs are employed. The last-named device is considered first since equal capillaries are still involved.

High-sensitivity magnification in free manometry with equal capillaries and two (equal) reservoirs. The general condition of Boyle, $PV =$ a constant, must be satisfied for any given value of x at constant temperature. To obtain maximum sensitivity magnification in constant-volume manometry, one must maximize ΔP by minimizing the change in gas volume so that $\Delta V \sim 0$. To obtain maximum sensitivity magnification in free manometry, it is conversely necessary to maximize the volume change by minimizing the pressure change so far as possible. This can be most effectively accomplished by constructing, as in the Braun-Fritzsching duplex manometer (*19*), a second reservoir at the top of the closed arm of area and height the same as that of the reservoir at the top of the open arm. The greatly increased area A of the added closed-arm reservoir, compared to the area a of the capillary contiguous below, will then operate in such a manner that a given change in amount of gas x will induce equal displacement of volumes of manometric fluid in the reservoirs and in the capillaries of both arms; but the total pressure change indicated by the algebraic sum of the fluid-distance displacements in the two reservoirs will be very small, even though not reducible to zero. At the same time the fluid-distance displacements in the capillaries, which may be readily followed and measured in either or both capillaries by means of inserted air bubbles, will be relatively large but will involve of themselves no net change in pressure since the heights and amounts of fluid in the capillaries will remain unchanged, even though the bubbles are moved. The fluid-distance displacements in the capillaries and in the reservoirs will vary inversely with their respective areas a and A, for given values of x and k.

To obtain greatest minimization of pressure change clearly requires the employment of both reservoirs, since if use is made of only one, a considerable and undesirable change in total height of fluid will occur in the other arm and, hence, a considerable change in pressure of the confined gas per change in x. Reservoirs in free manometry may be regarded as devices to reduce or minimize the positive magnitude of $\Delta P/x$ and, for maximum effect, must obviously be present and active on not just one but both arms. In constant-volume manometry the use of a closed-arm reservoir is superfluous and cannot provide any gain in sensitivity magnification M, since upon continued resetting of the bubble to a constant mark no pertinent change in the closed arm is ever developed (*19*).

The change in gas pressure ΔP^{**} induced by a change x, with the two-reservoir arrangement, may be measured and expressed in terms of the two observed equal-capillary fluid-distance displacements H^{**} and the two different areas a and A involved: $\Delta P^{**} = H^{**}a/A + H^{**}a/A = 2H^{**}a/A$. Then, similarly as before, $K^{**} = x/H^{**} = 2ka/A + (a \cdot 273/T')[(P + 2H^{**}a/A)/P_o] \cong (2ka/A) + (a \cdot 273/T')$, and if a/A is made very small then $K^{**} \cong a \cdot 273/T'$, and when a itself is made very small, K^{**} approaches zero and the theoretical sensitivity magnification, $M = k/K^{**} = H^{**}/h$, approaches infinity! In practice, however, capillaries of diameter less than 0.25 mm, corresponding to area values of a less than 0.05 mm², are too difficult or (in accordance with Bernoulli's theorem) too slow to work with (*20, 21*), so that sensitivity magnification values reach a practical limit in equal-reservoir, equal-capillary free manometry of $M = k/(0.05) \cong 20$ per each manometer arm (40 per both together), for normal k values of the order of unity, and greater or less than 20 (or 40) when k is greater or less than unity—that is, greater when v_G/v_F is increased and less when a, P_o, and T are increased. In any event practical, high M-values are readily attainable in suitable two-reservoir free manometry that equal or even surpass those earlier indicated as obtainable in practice in constant-volume manometry, namely, 15 to 30. Such magnifications will frequently be far more than desired and more than adequate to uphold the maxim of science that to increase sensitivity by an order of magnitude ($\sim$10-fold) is to open new worlds for study.

Experience and calculation show that, for maximum practical effect in any type of hydraulic-leverage magnification arrangement applicable to ordinary commercially available manometers, the arm reservoir area A need seldom be greater than the areas obtainable with diameters of 6 to 10 mm ($A = 30$ to 75 mm²) unless a is exceptionally large (> 3 mm²; diameter > 2 mm). With small values of a (which are preferable in order to obtain small values of a/A), the heights of the even-bore sections of the reservoirs need be only a few millimeters, and the total volume of the reservoirs less than 1 cm³. Calculations based on the equations for K^{**} given in the preceding paragraph will also show that capillaries of

area a 1 mm² and greater will seldom yield high magnification ($M \gg 1$) in two-reservoir free manometry, no matter how large the reservoir area in the expression for K^{**} is made, since the $a \cdot 273/T'$ component of K^{**} then always amounts to at least ~ 1 and, hence, values of $k/K^{**} = M \sim 1$ (*19*), except in the unusual cases when $k \gg 1$.

Ordinarily, therefore, for *high* M values with equal-capillary free manometry, not only are two reservoirs required but also values of a somewhat less than 1 mm² down to a practical limit of, say, 0.05 mm². However, there yet remains another series of hydraulic-leverage arrangements whereby it is possible in free manometry to obtain intermediate, even if not high, values of M, and these arrangements do not definitely require either of the two particular reservoirs just described or any permanent alteration of the glass construction of available manometers such as is involved when one adds the second reservoir to the closed arm of a manometer at hand. In the three-arm manometers described here, use is made of ordinary unaltered commercial Warburg manometers of large capillary bore to which is added a third arm of either of two types (vertical or horizontal), of very small capillary bore, in a form that is optionally removable or permanent and can be made in the laboratory or commercially.

Free manometry with unequal capillaries. Although in fixed-volume manometry a difference in capillary area between the open and closed arms is of no notable consequence for fluid-distance displacement changes observed in the open arm, the scope of free manometry can be greatly extended by the use of capillaries with markedly unequal areas in conjunction with either one or two reservoirs. The use of one reservoir alone with two unequal capillaries can be made to yield high-sensitivity magnifications nearly as striking in practice as those obtained with two reservoirs and equal capillaries already described. This is true because marked inequality between capillary areas is algebraically equivalent, and therefore under properly chosen conditions nearly numerically equivalent, to inequality between reservoir and capillary areas. This situation makes the construction of the second reservoir unessential to obtaining large M values in free manometry of some form or other and leaves as alternative the construction of a manometer with one fine capillary arm, preferably the open arm since a reservoir is more easily mounted thereon, and a bubble inserted therein.

With the manometer arrangement just indicated—open-arm reservoir, small capillary, and bubble—the change of gas pressure in the confined space is given by the sum of the algebraic fluid displacements in the open-arm reservoir and in the closed-arm capillary, thus, $\Delta\overline{P} = \overline{H}a/A + \overline{H}a/a^* = \overline{H}(a/A + a/a^*)$, where $\overline{H}$ is the measured bubble distance displacement in the open capillary, a and A are (as before) the areas of the open-arm fine capillary and reservoir, respectively, and a^* is the area of the closed-arm capillary. Then $\overline{K} = x/\overline{H} = k(a/A + a/a^*) + (a \cdot 273/T')\{[P + \overline{H}(a/A + a/a^*)]/P_o\} \cong k(a/A + a/a^*) + (a \cdot 273/T')$. (This equation also covers the more general situation of *two* reservoirs and *unequal* capillaries if a^* is regarded as the area A^* of the confining fluid in the closed-arm reservoir rather than the closed-arm capillary to which it is algebraically equivalent).

With practical values of $a = 0.05$ mm² (diameter, 0.25 mm), $a^* = 3$ mm² (diameter, 2 mm), and $A = 50$ mm² (diameter, 8 mm), $\overline{K} \cong k(0.05/50 + 0.05/) + 0.05 \cong 0.066$ for k of unity, so that a sensitivity magnification value of $M = \overline{K} \cong k/0.066 \cong 16$ is readily feasible, based on reading the bubble movement in the one arm only and without any resetting to fixed volume in the other arm. Since a^* could be made still larger, and hence M also, the practical limit of sensitivity magnification is largely governed, under these conditions, by the single magnitude $a \cong 0.05$, or $M \cong 20$! One has attained here, in essence, a volumeter operating at virtually constant pressure.

Warburg-type manometers with markedly unequal capillaries of the order of the dimensions just indicated would make excellent general-purpose manometers for both free and fixed-volume manometry, either with or without high-sensitivity magnification (with or without actual use of the reservoir-bubble arrangement). The unequal capillaries would offer no essential disadvantage for ordinary, conventional fixed-volume manometry but would open up a whole field of heretofore unenvisaged possibilities for free manometry. The widespread scientific utilization of such a type of all-purpose hydraulic manometer with two reservoirs (Fig. 4) deserves highest recommendation.

In the absence of such manometers at hand, it is possible to convert, in the laboratory or otherwise, the

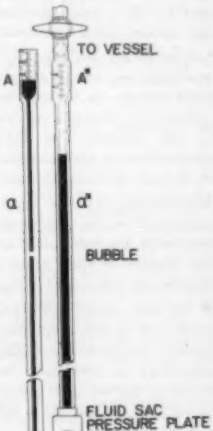

Fig. 4. Hydraulic general-purpose manometer designed for equally efficient use in either constant-volume manometry, free manometry, volumetry, or (Fig. 5) one-arm manometry, with either high-sensitivity magnification or conventional sensitivity: A and A^* are areas of outer and inner-arm reservoirs, ~ 30 mm² (diameters ~ 6 mm); a is area of outer-arm capillary of diameter optionally variable between, say, 0.25 to 2 mm; and a^* is area of inner-arm capillary of diameter optionally variable between, say, 1 to 2 mm. The customary graduations (not shown) of the capillary arms are extended to the tops of the reservoirs, and manometers with outer arms graduated over the range 0 to 500 mm may be mounted on standard commercial manometer backs normally supporting standard Warburg manometers of conventional range 0 to 300 mm. Outer and inner arms are readily separable and interchangeable at the fluid-sac juncture, permitting a wide range of K values dependent upon variable values of a/a^*, a/A^*, a^*/A^*, and so forth.

conventional, equal-capillary Warburg manometers into volumeter forms (three-arm manometers) that are equivalent to those with capillary inequality, two types of which are briefly described and analyzed.

To the open arm of an ordinary Warburg manometer filled to the top of the reservoir with manometric fluid, there is attached (by pressure tubing, plastic tubing, or glass ground jointing) an inverted, graduated, fine capillary U-tubing that rises and then descends, as a third manometer arm, the parallel length of the two other arms, to dip into an open reservoir filled with manometric fluid whose level is conveniently about that of the bottom of the two other arms. By means of the adjusting screw (or otherwise) the fluid in all three arms is made continuous except for insertion of a small air bubble in the U-tubing. This bubble may be inserted by lowering the reservoir fluid level momentarily below the end of the U-tubing and allowing a short length of air column to enter, with the aid of regulation by means of the adjustable screw.

The mathematical treatment is the same as is given in the preceding section, with a and A referring now to the areas of the capillary U-tubing and the test-tube reservoir, respectively. A can be made so large (several centimeters in diameter), if desired, that the term a/A in the formula for $\overline{K}$ drops out. The U-tubing can be made to extend far above the top of the manometer, and the bubble movement can be followed and measured over the entire length of both sides of the U-tubing, so that the scale length of fine capillary can be increased to several times the conventional scale length of 300 mm. It is possible to arrange for a series of machine-drawn capillary U-tubes of different areas, in order to obtain different values of sensitivity magnification desired (for example, 20, 10, 5).

A horizontal three-arm manometer variant consists merely of a long, graduated, fine capillary, attached to the second arm reservoir, as in the foregoing instance, but mounted horizontally. Fluid-distance displacement $\overline{H}$ readings are made simply at the end of the manometer fluid column in the fine capillary of area a, or optionally with an air bubble, or even with a small liquid bubble in an air column. The horizontal arrangement is perhaps geometrically less satisfactory, but experience shows that it is not without interest for the manometric hobbyist. Mathematically the term a/A in $\overline{K}$ is eliminated altogether, since the only hydrostatic pressure change involved occurs in the confining arm only and no longer at all in the middle or open arms, as is otherwise the case to some degree in all other arrangements previously described. $\overline{K}$ is now simply $\overline{K} = ka/a^* + (a \cdot 273/T^\circ)$, and a more than ever is the main determinant of sensitivity and sensitivity magnification. This brings us to the most remarkable type of hydraulic free manometry, in which neither a nor k alone, nor the sum of these invariably positive quantities, is the main sensitivity determinant, but their *difference* is.

One-arm, "paradox" free manometer. In all the manometric procedures considered so far, either with or without hydraulic leverage, an increase in amount of confined gas has caused an increase in pressure in practice, and never less than zero change in theory (volumetry), regardless of the number of arms per manometer or whether any of the arms are vertical or horizontal. When, however, an odd number of arms per manometer is involved (1, 3, or 5, and so forth), with the confining meniscus area A^* greater than area a^* of the open, terminal arm capillary declined at any angle greater than zero, preferably 90° for maximum effect, a truly astounding paradox and exceedingly useful result is obtained, invariably occasioning upon first acquaintance therewith by orectic hearers, temporary total disbelief: increases in amounts of confined gas cause notable *decreases* in pressure (Δp negative!), and vice versa. The vertical, one-arm, manometer with hydraulic confining reservoir (Fig. 5), but no terminal reservoir, is the most striking and simplest example to consider in detail.

In such a manometer, initially adjusted with manometric fluid in both the reservoir and capillary sections of the arm, a positive production of gas x in the vessel causes an increase in volume of confining gas space $H^\dagger a^*$, where $H^\dagger$ is the observed vertical lengthening (mm) of the fluid column in the capillary section of the arm as measured by the downward movement of the lower (hanging) meniscus in the capillary. Had there been, initially, fluid in the capillary portion only and none in the reservoir, there would have been column displacement without lengthening, and the increase in gas space would have been smaller than $H^\dagger a^*$, and the pressure change in the confined gas would have been, as in ideal volumetry, zero. The observed lengthening takes place as a result of the effect of the hydraulic factor A^*/a^*, but, contrary to all manometric arrangements considered previously, it does so not against, but in the same direction as (*with*), gravity, which acts as an added force to increase the gas space change. Since the opposing upward and downward pressures at the level of the hanging meniscus in the capillary section are always equal, atmos-

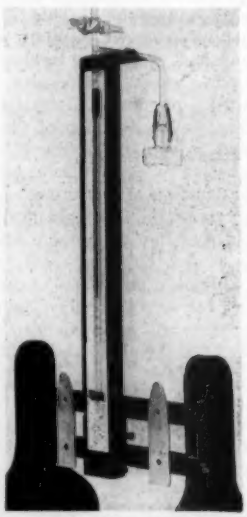

Fig. 5. Working model of the hydraulic, one-arm, "paradox" free manometer derivable from the hydraulic general-purpose manometer (Fig. 4) merely by removal of outer arm therefrom.

pheric (P_A), and unchanged by any change in x, and since the column length has been increased by a depth (not height) $-fH\uparrow$, it follows that the final pressure P_f of the confined gas has been decreased compared with the initial pressure P_i, and that the change in pressure $\Delta P\uparrow$ has been negative, $\Delta P\uparrow = (P_A - P_i) - (P_A - P_f) = P_f - P_i = -fH\uparrow < 0$, where the terms $(P_A - P_i)$ and $(P_A - P_f)$ refer to the initial and final hydrostatic pressures of the column (*22*). Obviously, with allowance for the shortening of the column in the reservoir, whose movement is opposite in sign from that in the capillary, $\Delta P\uparrow = -H\uparrow + Ha^*/A^* = -H\uparrow(1 - a^*/A^*)$.

From this expression for $\Delta P\uparrow$ it follows that the vessel "constant" of the one-arm manometer is $K\uparrow = x/H\uparrow = -k\,(1 - a^*/A^*) + (a^* \cdot 273/T')\{[P - H\uparrow(1 - a^*/A^*)]/P_o\}$, and no longer represents a sum but a difference of the two terms in a and k, as earlier adumbrated. This circumstance allows K↑ to become smaller than the a term previously limiting high-sensitivity magnification in free manometry. Positive values for $K\uparrow$ may decrease to zero and $M = k/K\uparrow$ may approach infinity. This yields the important practical result of eliminating the necessity for very small values of a, which may now be of the same order as k (say 1 to 2 mm²), with the very important added advantage of eliminating the slow response involved with small capillaries and at the same time retaining the main merit of free manometry, namely, no requirement for continual resetting to constant volume.

It is evident from the expression given for $K\uparrow$ that a wide range of possibilities, impossible to detail here but interesting to work out numerically and algebraically, offer themselves for obtaining any desired value of $K\uparrow$ and of $M = k/K\uparrow$ by varying the main components of $k(v_g, v_r, D)$, or A^* and a^* (relative and absolute values), or the initial height of the capillary-reservoir column that will affect the value of P, which is obviously always slightly below the prevailing atmospheric pressure P_A, and which must, like $H\uparrow$, be given due consideration when $K\uparrow$ is small. The initial height and stability of the capillary-reservoir column may be governed technically by means of a sac and screw clamp attached to the stopcock at the top of the manometer, or in various other ways unnecessary to detail here (*23*).

The eventual limitation to the use of the one-arm manometer is reached at high $M = k/K\uparrow$ values where small $K\uparrow$ values may not retain sufficient constancy over a wide range of observed $H\uparrow$ values. Since the exact formula given for $K\uparrow$ contains the then no longer minor variable $H\uparrow$ term, at small value of $K\uparrow$ (small differences between the terms in a and k), the expression within $K\uparrow$ in the braces can no longer be neglected as it could be in all previously reported approximation formulas for free manometry vessel constants, where a and k were additive in a positive sense only. This eventual limitation becomes especially significant when a^*/A^* is made small so that values of $H\uparrow/P_o$ for values of $H\uparrow = 100$ to 300 mm may then amount to an appreciable fraction of the entire term in a and, hence, in $K\uparrow$ when the latter is, say, 0.05 or less ($M \sim 20$). At this extreme range, the evaluation of $K\uparrow$ as a function of $H\uparrow$ will obviously require careful attention, involving some form of calibration (calculated or empirical), but this will be well worth while in view of the high speed of manometric fluid response to changes in x obtainable with one-arm manometry as compared with other highly sensitive forms of free manometry. Moreover, since high sensitivity is involved here, small values of $H\uparrow$ will frequently be sufficient for problems at hand; indeed the $H\uparrow$ values obtained may alternate plus and minus in sequence, as is commonly the case in problems such as photosynthesis, where $H\uparrow$ values of ± 10 mm per light-dark cycle may be entirely adequate, so that values of $M \sim 100$ could be obtained with satisfactory constancy of $K\uparrow$ as a function of $H\uparrow$.

It is a pleasure to acknowledge many helpful suggestions received from Jerome Cornfield, Erwin Fritzsching, Jehu Hunter, Hilton Lævy, Alan Mehler, Richard Schnier, Walter Slavin, Mark Woods, and the unknown referees. We are indepted to E. Machlett and Son, New York, for constructing and making available working models (*23*) of the general-purpose and one-arm manometers (Figs. 4, 5).

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6. K. Linderstrøm-Lang, *Compt. rend. trav. lab. Carlsberg* **24**, 334 (1943).
7. H. Holter, *ibid.* **24**, 399 (1943).
8. D. Glick, *Techniques of Histo- and Cyto-Chemistry* (Interscience, New York, 1949), p. 342.
9. The reference standard of *sensitivity* may be regarded as "millimeters of displacement of manometric fluid observed per cubic millimeter N.T.P. gas change," that is, $h/x = 1/k$; and for any given set of values of v_g, v_r, a, T, P_o; sensitivity *magnification* M is regarded in this paper as any form of amplification of h/x values, or reduction of k values, effected by various arrangements of hydraulic leverage-moving boundary index devices to be outlined. *Demagnification* may be regarded as any device or procedure for decreasing M, even to values below unity.
10. J. Barcroft and J. S. Haldane, *J. Physiol.* (*London*) **28**, 282 (1902).
11. The determination of vessel constants k, K, and various others (K', k^*, K^*, K^{**}, $\overline{K}$, $K\uparrow$) described throughout this paper are often better determined entirely empirically rather than by combinations of conventional mercury calibrations. The methods of Scholander, Niemeyer, and Claff (*12*) are very suitable, and their apparatus may readily be modified (and even simplified) to handle the smaller amounts of gas (smaller vessel constants) involved with high M values. It is recommended, however, that their procedure of calculation by formula be replaced by a procedure of direct comparison with a given standard manometer and vessel already accurately calibrated with mercury, carried out in such a manner that upon addition of identical quantities of gas to the standard and to the unknown manometer-vessel systems, the observed manometric fluid displacements will bear exactly inverse ratios to the desired respective vessel constants. This procedure has the advantage that it is not even necessary to know the quantity of gas added. Surprisingly accurate results, to within less than 1 percent, may be obtained when the gas is added at room temperature by means of an ordinary, tight-fitting, satisfactorily greased hypodermic syringe attached by pressure or plastic tubing to the manometer above the stopcock. Eminently satisfactory instruments for accurate delivery of small quantities of gas are available on the market. The indicated empirical methods have been found in practical experience to be especially convenient and suitable to the needs of hydraulic manometry.
12. P. F. Scholander, H. Niemeyer, and C. Lloyd Claff, *Science* **112**, 437 (1950).

13. $x = \Delta p^*(k + (a \cdot 273/T')\{(Ph^*/\Delta p + h^*)/P_o\})$.
14. A. Goldstein, *Science* **110**, 400 (1949).
15. ———, *Proc. Am. Acad. Arts Sci.* **77**, 237 (1949).
16. W. Arnold, E. W. Burdette, and J. B. Davidson, *Science* **114**, 364 (1951).
17. High shaking rates are often essential when using the standard rectangular Warburg manometric apparatus undergoing horizontal reciprocating motion, and it is often desirable or necessary to make readings without stopping the shaking. We have found (*18*) that by suitably mounting an ordinary hand lens, such as a standard equiconvex magnifying glass, on the carriage that supports and moves the manometers, any given manometer appears to the eye or camera to be *stationary* even though it may be shaking at a rate of 250 cy/min or more where unaided visual observations are unfeasible. This phenomenon is the result of an optical effect that reduces apparent motion to zero when the lens is mounted at approximately its principal focal length away from the manometer and moving with it in unison and in parallel, so as to produce collimated light. Whereas in principle any lens of ample size can be used, one with a focal length of 8 to 12 in. and a diameter of 3 to 4 in. has been found satisfactory (Fig. 6). The diameter of the lens should, of course, be as large as the shaking amplitude of the manometer, otherwise the image will disappear during part of the cycle. A lens with ample diameter will also increase the field of view, so that the manometers may be read when there are large changes in the displacements of the fluid indices observed, or where two adjacent manometers are to be observed simultaneously. For photography it is preferable that the lens employed be of a type corrected as in a telescope or binocular objective.
18. G. Hobby, V. Riley, and D. Burk, *An Optical Device for Reading a Rapidly Shaking Manometer or Other Reciprocating Apparatus*, in preparation.
19. The Braun-Fritzsching manometer has on each arm a reservoir of about 20 mm inside diameter and a capillary of about 1 mm inside diameter. This arrangement cannot provide notable sensitivity magnification in free manometry (see text) but only in constant-volume manometry, in which case the inner-arm reservoir is superfluous.
20. At least without making use of special wetting agents and of manometric fluids of exceptionally low viscosity and surface tension (*21*).
21. B. Kok, G. W. Veltkamp, and W. P. Gelderman, *Biochim. et Biophys. Acta* **11**, 10 (1953), Fig. 5.
22. Regarded in another way, since the sum of the hydrostatic pressure of the column and the pressure of the confined gas must always equal the prevailing atmospheric pressure (P_A), and since a positive increase in x causes a positive increase in hydrostatic pressure, it follows (by difference) that the pressure of the confined gas must decrease with positive values of x, and the change in pressure must be negative. Such *a priori* considerations can readily be confirmed experimentally by means of a conventional manometer connected in tandem with the one-arm manometer via vented plugs in the vessels of the two manometers. If gas is added to the one-arm manometer through its stopcock, the already described lengthening of its fluid column will be accompanied by a registered decrease of pressure in the conventional manometer operated either at free or fixed volume in the conventional manner without use of hydraulic magnification devices; that is, the column in the outer arm will fall. If, however, enough gas is added to the one-arm manometer to force all the liquid out of its reservoir down into the capillary below, then, from this point on, the column in the open arm of the conventional manometer will reverse its direction and rise, indicating now the customary increase in pressure with an increase of x in the system when the hydraulic factor A^*/a^* is no longer operating in the one-arm manometer.
23. Demonstrated at the meeting of the Society of General Physiologists, Woods Hole, Mass., 9 Sept. 1954.

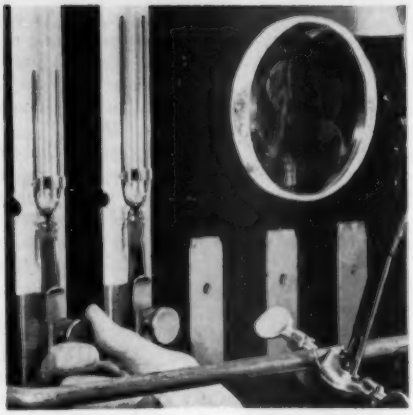

Fig. 6. Illustrative, simple arrangement for obtaining a stationary optical effect (zero apparent motion) with an equiconvex lens mounted at its focal distance and shaking in parallel and unison with a rapidly reciprocating manometer (*17*, *18*).

News and Notes

International Instrument Congress

The wide scope and large size of the 1st International Instrument Congress and Exposition, held under the auspices of the Instrument Society of America in Philadelphia, 13–24 Sept., afforded more than 23,000 persons a unique opportunity to view at first hand the intensive activity that characterizes the present-day field of instrumentation, to observe trends and to evaluate the impact of these trends on individual areas of interest. Although this was actually the ninth in an annual series of instrument conferences and exhibits of the Instrument Society of America (the 1st Instrument Conference and Exhibit was held in Pittsburgh in 1946), it was the first in which foreign countries were especially invited to participate. More than 70 foreign firms were represented in the exhibit; the number of foreign visitors is not yet known but was certainly well into the hundreds.

Official recognition and encouragement of this international participation was provided by two resolutions passed in the U.S. Congress and approved by the President. One resolution permitted articles imported from foreign countries for the purposes of this exhibition to be admitted without payment of tariff, and the other authorized the President of the United States to invite the states of the Union and foreign countries to participate in the congress and exposition. In accordance with this resolution, President Eisenhower issued a proclamation and then went further to signify his endorsement of the congress and exposition by sending a letter to the president of the Instrument

Society of America asking that Presidential greetings be conveyed to those attending.

Nearly 500 exhibitors displayed instruments for every field of application, every industry, every field of research. The cooperation of professional societies in arranging the technical sessions well illustrated the role of instrumentation as a common denominator linking the various traditional scientific and technical fields. Eleven societies assisted in arranging a program of 50 technical sessions in which approximately 160 papers were presented. A listing of these cooperating societies illustrates the interest that all technical fields have in instrumentation: American Institute of Chemical Engineers; American Institute of Physics; American Institute of Electrical Engineers; American Society of Photogrammetry; American Meteorological Society; American Microscopical Society; Institute of Radio Engineers; Society for Experimental Stress Analysis; Metropolitan Microchemical Society of New York; American Chemical Society; American Society of Mechanical Engineers.

Two Clinics were held in conjunction with the congress. One, consisting of eight 2-hr sessions, was the 5th ISA Instrument Maintenance Clinic, which offered instruction to several hundred instrument men and apprentices on maintenance of various basic types of instruments. The other, the 3rd annual Analytical Instrument Clinic, was a lecture and demonstration course on the latest analytic instruments. This was attended by more than 300 engineers, physicists, and chemists. Three-hour sessions were held on each of seven instruments: x-ray quantometer, Littrow-Echell spectrograph, process monitor mass spectrometer, infrared spectrometer, infrared analyzer, ion-resonance spectrometer, and nuclear magnetic resonance spectrometer.

Many of the technical papers presented will appear in forthcoming issues of the *Journal of the Instrument Society of America* or in the journals of the other societies. Preprints were available for most, and the ISA papers will be available in the form of *Proceedings*. A list of titles may be obtained from the ISA (1319 Allegheny Ave., Pittsburgh 33).

Some notable features and trends of the exhibit, in addition to the foreign displays, were the American Institute of Physics exhibition, which included not only the regular publications of AIP but also many books in various scientific fields having instrumentation interest; the large number of exhibits featuring automatic data-reading equipment with digital output; the trend toward using such advanced techniques as modular assembly, miniaturization, and etched circuits; and the continued trend toward rapid commercialization of highly specialized research instruments typified by the nuclear magnetic resonance (n-m-r) spectrometer.

The aisles of the exhibit hall were posted with the names of famous scientists and engineers who contributed significantly to instrumentation. A listing of these names recalls how much their enduring fame has rested on such contributions: d'Arsonval, Boys, Bunsen, Celsius, Coulomb, Elster, Fahrenheit, Franklin, Galileo, Geiger, Gilbert, Helmholtz, Huygens, Lord Kelvin, Rumford, Schweigger, Seebeck, J. J. Thomson, Torricelli, Venturi, da Vinci, Watt, Wheatstone.

At its annual meeting, the council of the ISA elected the following officers, who take office 1 Jan. 1955: pres., Warren Brand (Conoflow Corp., Philadelphia); v. presidents, A. A. Anderson (Swissomatic Products, Los Angeles) and W. H. Fortney (Humble Oil Co. Bay Town, Tex.); treas. J. T. Vollbrecht (Energy Control Co., N.Y.). Continuing members of the executive board include v. presidents, D. C. Little (Army Medical Research Center, Fort Knox) and A. H. Peterson (Mellon Institute, Pittsburgh); sec., R. T. Sheen (Milton Roy Co., Philadelphia); and retiring president W. A. Wildhack (National Bureau of Standards, Washington). The 10th Instrument Conference and Exhibit will be held in Los Angeles, 12–16 Sept. 1955.

Science News

H. Rowan Gaither, Jr., president of the Ford Foundation stated recently in the foundation's annual report that

> Today, timidity characterizes too much of our current corporate and individual giving. . . . There is an unfortunate tendency for donors to select the safe and sure—safe in the sense that few will criticize the gift; sure in that the result of the gift may be predicted.
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> This tendency, if it persists, will create a philanthropic imbalance by withholding support from areas which must be developed if we are to advance on a broad front. For progress requires the breaking of new and uncertain ground, and often it is surrounded by debate and controversy.

"We Accuse" is the title of a long article on the Oppenheimer case in the October issue of *Harper's* by Joseph and Stewart Alsop. The authors "accuse the Atomic Energy Commission in particular, and the American government in general, of a shocking miscarriage of justice. . . ." After presenting some biographical material, the authors review the six examples of "falsehood, evasion, and misrepresentation" with which the AEC finding was supported, and find only one to be "worthy of serious consideration"—the Chevalier incident, the most important aspect of which, "Oppenheimer's voluntary decision to give the warning about Eltenton," was not mentioned in the AEC opinion. The authors consider this omission to be "no mere caricature of the truth [about the Chevalier incident], but a gross and flagrant distortion . . . the judge himself indulging, wholesale, in the suppression of what is relevant and true, and the suggestion of what is irrelevant and false."

The authors also discuss at length the roles of Roscoe C. Wilson, David T. Griggs, and Edward Teller, as well as three of Oppenheimer's opinions on major issues of national policy: his moral, technical, and strategic objections to the hydrogen bomb; his favor-

able opinion on the tactical use of atomic weapons (Project Vista); and the recommendations of the Project Lincoln Summer Study Group on continental air defense. The authors describe specifically the unpopularity of Oppenheimer's opinions on the latter two questions with the Strategic Air Command.

On 29 Sept. it was reported that **radioactive dust** "presumably borne by winds from the explosion of a Russian nuclear weapon" had been detected by monitoring instruments at the Armour Research Foundation of the Illinois Institute of Technology, Chicago. The city's "radiation content" increased to approximately 700 counts/min, however this count is much less than that given off by a luminous dial wrist watch.

On the same day Japan's Atomic Injuries Investigation Committee issued a nation-wide warning against drinking unfiltered rain water or water from lakes and catchments because of strong radioactivity found recently in rain water in many parts of Japan. The radioactivity has been attributed to Russian hydrogen bomb tests in Siberia.

Jack Hemphill, a biologist for the Arizona Game and Fish Commission, has perfected a method for **preventing fish from being winter-killed** in ice-bound lakes. A channel is opened in frozen bodies of water by pumping compressed air through a perforated pipe anchored to the bottom. The compressed air forces the warmer water at the bottom to the surface and opens a channel. Thus light can reach green plants, which produce oxygen needed by the fish. Normally, light cannot penetrate the ice and thousands of fish succumb to asphyxiation.

Belgium and Switzerland signed an **atomic exchange agreement** shortly after President Eisenhower's recent announcement that the United States would help Belgium build an atomic reactor. Under the agreement Belgium will sell Switzerland small supplies of Congo uranium ore, the vital raw material Belgium formerly furnished only to Britain and the United States under a secret wartime treaty. The two nations also contracted to trade scientific information on construction, exploitation, and operation of atomic piles and reactors.

In 1955 Federal agencies will obligate an estimated **$1.99 billion for research** and development activities, about 10 percent less than the $2.23 billion for 1954, according to the report, *Federal Funds for Science, III. The Federal Research and Development Budget, Fiscal Years 1953, 1954, and 1955,* issued recently by the National Science Foundation.

The major decreases occurred in allotments for research and development plants and facilities—$158 million in 1955 compared with $227 million in 1954, and applied research and development, $1669 million in 1955 and $1703 million in 1954. Obligations for basic research in the sciences were expected to increase during the year from $120 million in 1954 to $131 million in 1955. These figures exclude approximately $176 million (1954) and $35 million (1955) of research and development funds available to the Office of the Secretary of Defense that were not allocated to specific programs at the time of writing.

About 87 ct of each dollar for scientific research and development went to the physical sciences; 11 ct went to the life sciences; and 2 ct to the social sciences. Research and development for national security accounted for about 85 percent of the Federal science expenditures, and the remaining 15 percent was divided among all other functions of government, including agriculture, health, welfare, transportation, communications, and development of natural resources.

British archeologists are resigned to the probability that the site of the Roman **temple of Mithras** recently unearthed in London will soon become the foundation of a new seven-story office building. Preservation of the 1500-yr-old temple is too costly.

In the 10 Oct. issue of *Nature* R. E. Pattle of the British Department of Scientific and Industrial Research's Chemical Research Laboratory reports an **"untapped source of power."** The osmotic pressure of sea water is about 20 atm. The British experiment put the osmotic pressure to work by separating alternate layers of salt and fresh water by alternate basic and acidic membranes that incorporate ion-exchange resins. When such membranes separate salt solutions of different strengths, a potential difference appears. The membranes are connected in series. A hydroelectric pile of 47 pairs of membranes each 3 in. square yielded a maximum of 15 mw output power. At low temperatures the internal resistance is higher and the power output is lower. The pile is therefore likely to be more successful in a warm climate. Whether the process will be economical probably depends upon the time it will run before the membranes need replacing and the interior needs cleaning.

A **ring holding a radioactive chemical** is worn by women factory workers who must put their hands dangerously close to a cutting tool on a machine. When the hand comes to the danger line, the detection instrument clicks. The worker does not have to listen for the signal to pull her hand back, for the click of the instrument stops the machine. A description of this device, was included in a recent speech by Brig. Gen. Elbert DeCoursey, director of the Armed Forces Institute of Pathology.

In a recent issue of the *Journal of the American Chemical Society* Bert L. Vallee of the Biophysics Research Laboratory, Harvard Medical School and Peter Bent Brigham Hospital, and Hans Neurath, professor and head of the department of biochemistry at the University of Washington in Seattle, report that **zinc is an essential component** of an enzyme needed in digestion. Analyses of several independent crystalline preparations of carboxypeptidase, an enzyme obtained from the pancreas of cows, showed that there is exactly one atom of zinc in each molecule. Carboxy-

peptidase acts on the linkages of protein decomposition products and reduces them to amino acids, which are essential in human nutrition.

Identification of the zinc in the enzyme was made as a result of the Harvard laboratory's continuing investigation of the role of metals in cell metabolism and of Neurath's very extensive research on the function and structure of proteins. The coordination of the independent efforts of both laboratories resulted in the successful collaboration.

The U.S. Department of Agriculture's Forest Products Laboratory at Madison, Wis., has developed a new test for detecting **southern pine decay.** When a solution of alizarin red S is applied to the ends of southern pine stock, decay-infected areas turn yellow; healthy wood turns a bright red.

In an article entitled **"Spreading the Fruits of Research"** in the September *American Mercury*, John L. Kent, science and industry correspondent of Washington, D.C., discusses the dissemination of research information by the government bureaus. He says that "red tape, excessive security, and lack of a system are slowing the flow of reports to those who could make use of them." He cites instances in which reports of important nonmilitary research were not made available to industry and other researchers until 3 yr after the reports were written.

The author suggests that an industry-government committee, similar to the one that studied the Atomic Energy Commission dissemination problems several years ago, be organized to "examine the unclassified and perhaps over-classified research reports of the Departments, and look into the nonmilitary departments as well. . . . The mere existence of such a committee would probably speed up dissemination. . . ." Kent thinks that the National Advisory Committee for Aeronautics, the National Bureau of Standards, and the Atomic Energy Commission are doing a good job of disseminating technical information.

In September **Australia's first crushing of uranium** ore began in Rum Jungle in the Northern Territory, an area once considered almost worthless. In 1948 the Commonwealth Government offered rewards up to £25,000 for significant discoveries of uranium. Joe White of Darwin, for 20 yr a gold and copper prospector, recognized in a Government pamphlet a photograph of ore that reminded him of specimens he had seen at an old copper working in Rum Jungle. He sent samples of this ore to the Mines Department at Alice Springs and received the award.

The mountainous **Palmer Peninsula** in the Falkland Islands region of Antarctica is to be mapped and investigated by eight scientists and surveyors who recently left England on a 2-yr expedition. The expedition is officially classified as a routine replacement of personnel already in the area. The Falkland Islands are a British Crown Colony. In 1908 Britain annexed in addition South Georgia, the South Sandwich Islands, South Orkney Islands, South Shetland Islands, and the Palmer Peninsula together with its offshore islands, as the Falkland Island Dependencies. Argentina disputes the British claim to the Falklands, and both Argentina and Chile dispute the claim to the dependencies. Great Britain is establishing a chain of meteorological and other stations in the area.

The main base camp of the current expedition will be established at Hope Bay in Graham Land on the northern tip of the peninsula. Sledge parties will explore the interior next spring. Many lines of research, including ionospheric surveys, will be carried out.

Palmer Peninsula itself is thought to be a geologic continuation of the Pacific Coast volcano chain extending from the Rockies to Tierra del Fuego. According to a report by members of the preceding expedition, bones of penguins bigger than men have been found on Seymour Island off the eastern coast of the peninsula. London paleontologists declared the specimens to be relics of a fossil race of penguins that flourished in the Miocene period 25 million yr ago.

Scientists in the News

Four new appointments to the staff of the National Science Foundation have been announced:

Lawrence R. Blinks of the Hopkins Marine Station, Stanford University, is assistant director for biological and medical sciences.

George H. Hickox of the University of Tennessee, is program director for engineering sciences in the mathematical, physical, and engineering sciences division.

William C. Steere of Stanford University, is program director for systematic biology in the biological and medical sciences division.

Peter van de Kamp, of Swarthmore College, is program director for astronomy in the mathematical, physical, and engineering sciences division.

John G. Reinhold, biochemist noted for his research in liver diseases, received the 1954 Ernst Bischoff award of $500 at the 6th annual meeting of the American Association of Clinical Chemists. Reinhold is associate professor of physiological chemistry in medicine at the Graduate School of Medicine, University of Pennsylvania, and is in charge of chemistry at the Pepper Laboratory of Clinical Medicine at that institution.

At a recent ceremony in Princeton, N.J., **Albert Einstein** and **James Franck** of the University of Chicago received honorary degrees from Technion, Israel Institute of Technology. Two other Nobel prize winners were present—Niels Bohr, Danish physicist, and Isidor I. Rabi, nuclear physicist and member of the General Advisory Commission of the Atomic Energy Commission. Some 150 educators, Israeli officials and Jewish leaders attended the function, which was under the auspices of the American Technion Society.

Ernest Edward Charlton, consultant in nucleonics and radiation at the General Electric Research Laboratory at Schenectady, has been chosen as the Mehl honor lecturer for the annual convention of the Society for Nondestructive Testing, to be held in Chicago, 1–4 Nov. at the Morrison Hotel.

George Glockler, formerly deputy chief scientist of the Office of Ordnance Research, U.S. Army, and a past vice president of the AAAS, has been appointed chief scientist of OOR. He succeeds T. J. Killian, who resigned recently to become dean of the School of Engineering and Architecture at Catholic University.

Henry J. Oosting, plant ecologist, has been named chairman of the Duke University botany department. He succeeds **Hugo L. Blomquist,** who has held the post since 1934. Though retiring from the chairmanship, Blomquist will continue to serve in the department as a full professor.

Robert R. Wilson, director of Cornell University's Newman Laboratory of Nuclear Studies, is at the University of Paris as a consultant in the construction of an electron accelerator of the synchrotron type. In addition to working on the accelerator, he will lecture at the Sorbonne as well as the University of Paris before his return to Ithaca in February.

Sharp and Dohme, division of Merck and Co., Inc., has announced the retirement of **Paul S. Pittenger,** vice president and director of quality control. Pittenger joined the H. K. Mulford Co. as director of pharmacodynamic research in 1910, and held that position until 1925. Two years later he was appointed director of pharmacologic research at Sharp and Dohme, which named him assistant general superintendent in 1928 and assistant to the president in 1929. He became vice president in 1930 following the merger of Sharp and Dohme and H. K. Mulford.

In addition to his positions in industry, Pittenger for 20 yr served as demonstrator, lecturer, and instructor in bioassaying at the Medico-Chirurgical College of Philadelphia, the Philadelphia College of Pharmacy and Science, and Temple University College of Pharmacy. His course in bioassaying was the first to be offered in the United States.

The American Society of Medical Technology has designated **John William Chubbuck,** editor of the *Newsletter* of the Texas Society of Medical Technologists, as winner of the Medical Technologist of Texas award.

Abram V. Tunison has been promoted to the position of chief of the Fish and Wildlife Service's branch of game fish and hatcheries. He succeeds **O. Lloyd Meehean,** who was appointed recently as assistant to the director in charge of technical staff services. **William Hagen, Jr.,** chief of the section of salmon propagation, will become assistant chief of the branch of game fish and hatcheries, filling the vacancy left by Tunison.

Carl Tolman, who has been associated with Washington University, St. Louis, as a member of the faculty and in various administrative posts since 1927, has been named vice chancellor and dean of faculties. Tolman has been acting in that capacity since June 1953. Since 1946 he has held the position of dean of the Graduate School of Arts and Sciences, and for the past 9 yr he has also been professor of geology and geological engineering and chairman of that department.

The Department of the Army has appointed **Per K. Frolich,** vice president of the chemical firm of Merck and Co., Inc., Rahway, N.J., to the top civilian post in the Army Chemical Corps. Expected to take office about 1 Dec., he will serve in the dual capacity of deputy chief chemical officer for scientific activities, and chief scientist for the corps.

Recently **Sydney Chapman,** president of the International Union of Geodesy and Geophysics, Great Britain, and chairman of the special committee for the International Geophysical Year, spoke at the National Science Foundation on "Rocket exploration of the geomagnetic field."

At Wesleyan College, Macon, Ga., **Mary Nancy Green** has resigned to join the department of chemistry at Wellesley College, and **Lisabeth Beynon,** formerly of Mercy College, Detroit, Mich., has accepted a chemistry professorship.

Geoffrey Edsall, editor-in-chief of the *Journal of Immunology* since December 1948, has resigned effective 1 Oct. His successor is **John Y. Sugg,** associate professor of bacteriology and immunology, Cornell University Medical College, 1300 York Ave., New York 21.

Charles R. Holmes, research geophysicist of the New Mexico Institute of Mining and Technology, has just returned from 2 yr of study and research at Pennsylvania State University. He will resume his studies of underground water resources.

Arthur D. Little, Inc., industrial consulting and research firm in Cambridge, Massachusetts, has announced that **Charles M. Apt** joined the staff of the Flavor Laboratory in August. Apt had previously served on the faculty of Amherst College, where he taught physics and analytical and general chemistry. He also conducted research in light-scattering from solutions of nucleic acids isolated from mammary adenocarcinoma tumor tissue in mice.

John M. Neff, former assistant manager of the ceramics and minerals research department at Armour Research Foundation of Illinois Institute of Technology, has been promoted to manager. He succeeds **Einar P. Flint,** who resigned to accept a position as director of inorganic research at the Mallinckrodt Chemical Works, St. Louis, effective 1 Oct.

New York University College of Medicine has announced that **William C. Von Glahn,** chairman of the department of pathology, has retired with the title of professor emeritus. He is succeeded by **Lewis Thomas,** former professor of pediatrics and internal medicine at the University of Minnesota Medical School. Von Glahn received his M.D. from the Johns Hopkins University Medical School in 1915. Prior to joining N.Y.U. in 1941, he held teaching appointments at Johns Hopkins and the College of Physicians and Surgeons, Columbia University. He has served on the staffs of Johns Hopkins Hospital and City Hospital in Baltimore, and of Presbyterian Hospital, Bellevue Hospital, and New York University Hospital in New York. In addition to other society affiliations, Von Glahn is a past vice president and president of the New York Pathological Society and past president of the New York Clinical Society.

Norton Nelson, professor of industrial medicine in the Post-Graduate Medical School of New York University–Bellevue Medical Center, has been appointed director of the Institute of Industrial Medicine at the center. He succeeds Anthony J. Lanza, who becomes a consultant to the institute.

James M. Sharp, recently associated with atomic energy development programs at the Sandia Corp. and the Air Force Special Weapons Center, has been appointed supervisor of special projects for the physics department of the Southwest Research Institute. He will be responsible for industrial and military research operations in systems analysis, analog computers, energy conversion methods, and electromechanical development.

Necrology

Henry F. Beckman, 78, professor emeritus of obstetrics at Indiana University Medical School, Bloomington, Ind., 5 Oct.; **Nolan R. Best,** 38, rocket and guided missile expert at the Naval Research Laboratory, Washington, D.C., 29 Sept.; **John L. Flagg,** 81, president of the Watson-Flagg Engineering Co., New York, N.Y., 2 Oct.; **Roderic Hill,** 60, retired air chief marshal and rector of the Imperial College of Science and Technology, London, Eng., 6 Oct.; **Luther G. Paul,** 83, retired surgeon and former professor of medicine at Harvard University, Cambridge, Mass., 6 Oct.; **Charles W. Perkins,** 76, surgeon, radiologist, and author, Norwalk, Conn., 7 Oct.; **James M. Phalen,** 81, surgeon, specialist in tropical diseases, author, and editor emeritus of the *Military Surgeon,* Washington, D.C., 5 Oct.; **Ward E. Pratt,** 64, chemical engineer, expert on metal corrosion, and inventor, West Orange, N.J., 5 Oct.; **Edward C. Schneider,** 80, pioneer in aviation medicine, developer of Schneider physical fitness index, and professor emeritus of biology at Wesleyan University, Middletown, Conn., 3 Oct.; **Alfred M. Tozzer,** 77, former curator of Middle American archeology and ethnology at the Peabody Museum, Hudson professor of archeology and professor emeritus of anthropology at Harvard University, Cambridge, Mass., 5 Oct.; **Robert S. Wilson,** 38, nuclear physics investigator at the Australian National University, Melbourne, Australia, 4 Oct.; **Monte M. Wladaver,** 53, physician and research specialist in the preservation of woods.

Meetings

Potential industrial health hazards, as well as the major health problems now facing manufacturers, will be taken up at the 19th annual meeting of **Industrial Hygiene Foundation** to be held at Mellon Institute, Pittsburgh, Pa. 17–18 Nov. Some 800 industrial and professional leaders from all parts of the United States will participate in medical, engineering, chemical-toxicological, legal, and joint medical-legal conferences on the first day and in the main meeting, designed particularly for management, on the 18th. They will represent the 360 member companies of the foundation.

The **American Society of Tropical Medicine and Hygiene,** the American Academy of Tropical Medicine, and the American Society of Parasitologists, will meet together in Memphis, Tenn., 3–6 Nov.

The 40th annual clinical congress of the **American College of Surgeons** will be held in Atlantic City, N.J., 15–19 Nov. More than 10,000 fellows of the college and their guests from all over the world will participate in this postgraduate education meeting. Charles deT. Shivers of Atlantic City is chairman of the Atlantic City Advisory Committee on Arrangements.

Frank Glenn, New York, current president of the college, will preside at the opening evening session at which Alan Gregg, New York, and Robert H. Kennedy, New York, will be guest speakers. On the final evening Alfred Blalock, Baltimore, will be installed as president for the coming year. Evarts A. Graham of St. Louis is chairman of the board of regents and Paul R. Hawley of Chicago is the director.

The **Southeastern Work Conference on Biology Teaching,** 28 Aug.–6 Sept., was sponsored by the National Association of Biology Teachers in cooperation with the American Institute of Biological Sciences. It was made possible by a $15,000 grant from the National Science Foundation and was codirected by Richard L. Weaver, associate professor of conservation at the University of Michigan, and Samuel Meyer, head of the botany department at Florida State University. There were nearly 100 participants in the conference, a group that was made up of college professors of botany, zoology, biology, and science education; high school teachers of biology; and supervisory and administrative personnel, including deans and state superintendents of education. Seventeen states, the District of Columbia, and the Canal

Zone were represented. Delegates from the AAAS, the National Research Council, and the National Science Foundation took part.

Using group discussion methods, biology teaching in high schools and colleges was considered from many viewpoints, such as that of the research biologist, the college teacher, the methods teacher, the secondary school teacher, and of administrative officers at all levels. Basic problems of all groups were presented and considered by the entire conference, the first to bring together a large number of people from all levels of teaching and administration for simultaneous consideration of problems in the teaching of biology. The total biology training program from the introductory high school biology course through advanced professional training of biology teachers and researchers was brought into sharp focus.

Many of the problems discussed related to the acute shortage of qualified high school biology teachers. The U.S. Office of Education has recently issued a statement that less than 60 percent of the high school biology teachers have the equivalent of a college major in that field. As high school enrollments increase, the shortage is becoming more acute. At the same time, an increasing number of high schools are requiring all students to have courses in biology and a decreasing number of college graduates are choosing high school biology teaching as a profession. The conference approached this problem from two standpoints: to improve the quality of training for the high school biology teacher, and to make his job more attractive after he has gotten into it.

To improve training, the conference recommended that the prospective high school biology teacher have a college major in biology which will include one year of general biology or courses in general botany and general zoology; at least one-third of this training should be in plant science. The conference recognized the need for field studies in the teacher's advanced training. To provide a broad training that will make modern biology meaningful and at the same time qualify the teacher to instruct in related scientific fields, it was recommended that he have a year each of chemistry and physics, with laboratory work, a year of mathematics, and some training in earth science. It was further recommended that he take the necessary education courses to fulfill his state's certification requirements. A course in the methods of teaching high school biology was considered essential. It was agreed that the high school biology teacher should have the same broad training in the humanities, social studies, and communication skills as teachers in other areas. The conference regarded these recommendations as the minimum training needed by the high school biology teacher to prepare him for his work.

The conference recognized the high school teacher's need for consultative services. It was felt that too often other assignments in the consultant's schedule took precedence over providing advice. For that reason, it was recommended that the various states take the necessary steps to concentrate their consultant services in the hands of a single individual who would have no other major responsibilities.

In order to meet the demands for increased numbers of high school biology teachers, the conference suggested that this position be made more attractive (i) by the establishment of salary and pension schedules more nearly comparable to those of other professional groups in industry and government, (ii) by encouraging promising high school students to choose biology teaching as a profession, (iii) and by issuing temporary certificates to persons who do not meet the minimum requirements provided they continue their professional training toward meeting such requirements.

The conference recognized that the high school student is to be training to take his part in community life and that his work in biology should make a definite contribution to that goal.

A symposium on **The Nuclear Reactor and the University** will be given 12–13 Nov. by Vanderbilt University in cooperation with Oak Ridge National Laboratory and the Oak Ridge Institute of Nuclear Studies. Eight persons—four from Oak Ridge National Laboratory, two from the Atomic Energy Commission, and two from the university—will give papers at the symposium, which will be held on the Vanderbilt campus in Nashville. All interested engineers and scientists are invited.

Available Fellowships and Awards

On 24 Sept. the **Rockefeller Foundation** took action that provided a grant of up to $30,000 for the **Gordon Research Conferences of the AAAS.** The money is to be used for the payment of expenses involved in the attendance of foreign scientists at the more biological of the conferences. The fund is available during the 3-yr period beginning 1 Jan. 1955. Up to $12,000 may be used in any one year.

The **Life Insurance Medical Research Fund** invites faculty members to nominate for 1955–56 predoctoral fellowships medical students who wish to spend a year in research training. *Nomination deadline is 30 Nov.* These fellowships are open to those who have completed 1 yr or more of work as a medical student. Stipends are from $2000 to $2400. For further information write to the Scientific Director of the Fund at 345 E. 46th St., New York 17.

The **Lalor Foundation** has announced a new program for 1955 to include 20 summer or interim awards to college and university faculty members for study and research in which chemistry or physics is used to attack problems in any of the biological sciences. Each award will normally not exceed $900 to single men and women and $1100 to married persons, unless there are special circumstances.

It is the hope of the foundation that not only sig-

nificant research, but also more dynamic teaching of science may result from this new program and that younger faculty members may find opportunity by this means to advance in their profession. The foundation is discontinuing its previous program of full-year predoctoral and postdoctoral fellowship awards. Detailed information about the new program may be obtained from C. L. Burdick, Director, Lalor Foundation, 4400 Lancaster Pike, Wilmington 5, Del. *Applications must be filed before 15 Jan. 1955.*

Instruments

Beckman has announced a new ultraviolet near-infrared **spectrophotometer** with a wavelength range of 220 to 2700 mμ. The instrument has a lead sulfide detector and a quartz monochromator to permit high-speed transmittance recording. It provides double-beam operation with a single receiver and fast-beam chopping (480 times/sec). The resolution is 0.1 mμ at 220 mμ and 5 mμ at 2500 mμ. Any of five scanning speeds can be selected. (Bull. 352–38, Beckman Instruments, Inc., Dept. Sc., Fullerton 1, Calif.)

A **blood arithmometer** has been designed to make complete blood counts automatically. After a sample is placed in the counting chamber, a built-in microscope with dark-field illumination images the cells in the plane of a precision aperture located in front of a photomultiplier. As the counting chamber is scanned by a light beam, cells with images either wholly or partly within the area of the precision aperture are detected. The photomultiplier detects each image that passes across its cathode, and the resulting electronic pulses are fed into a computer circuit. The count is displayed on a dial calibrated in terms of 10^6 red cells/mm^3 and 10^4 white cells/mm^3. The accuracy is ±3 percent. (Jarrell-Ash Co., Dept. Sc., 26 Farwell St., Newtonville, Mass.)

A new high-speed **microoscillograph** is available for the single-sweep recording of three simultaneous phenomena at frequencies up to 10,000 Mcy/sec. Three beams and three independent electrostatic deflection systems are provided. The beams are focused to writing spots 0.01 mm in diameter by an electromagnetic lens. Records are made on a photographic plate big enough for 27 oscillograms; it is inserted into the vacuum chamber through a vacuum lock. (Central Research Laboratories, Inc., Dept. KP-Sc., Red Wing, Minn.)

Miscellaneous

The Rockefeller Institute for Medical Research announces the publication of a new journal to be known as ***The Journal of Biophysical and Biochemical Cytology.*** It will be the purpose of this new publication to provide a common medium for the presentation of morphological, biochemical, and biophysical studies of the structure of cells and their components and of the functions of these components. The *Journal* will give special attention to investigations dealing with cellular organization at colloidal and molecular levels. Papers will be favored which integrate information derived from newer approaches to cytology, such as histochemistry, cytogenetics, cytochemistry, electron microscopy, and x-ray diffraction.

Because of the significance of photographic evidence, the publishers of the Journal will endeavor to insure excellence of photoengravings and printing. The length of articles will be limited to approximately 25 printed pages exclusive of plates. Short notes of 1500 words or less will be accepted; review articles will be published only on invitation. The format and styling used by the *Journal of Experimental Medicine* and the *Journal of General Physiology*, presently published by The Rockefeller Institute, will be followed by this new *Journal*.

It is proposed to publish one volume per year, the issues appearing bimonthly: the price will be $7.50 per volume. In order that manuscripts may be considered for inclusion in the first number which will be published in January 1955, they must be received *not later than 1 Nov.*

The *Journal* will be edited by Richard S. Bear, Massachusetts Institute of Technology; H. Stanley Bennett, University of Washington; Albert L. Lehninger, Johns Hopkins University; George E. Palade, Rockefeller Institute; Keith R. Porter, Rockefeller Institute; Francis O. Schmitt, Massachusetts Institute of Technology; Franz Schrader, Columbia University; Arnold M. Seligman, Sinai Hospital of Baltimore. Manuscripts should be addressed to the Editors, *The Journal of Biophysical and Biochemical Cytology*, The Rockefeller Institute for Medical Research, New York 21.

The following **chemicals** are wanted by the Registry of Rare Chemicals, Armour Research Foundation of Illinois Institute of Technology, 35 W. 33 St., Chicago, Ill.: tangeretin; thevetine; murexine; meroxyl; crotonyl isothiocyanate; ketoglutaric aminase; cyclophorase; 4-ureido-5-imidazole carboxylic acid; nobiletin; arecolidine; beta-ortho-cresyl glutaric acid; mucinase; para-iodophyenyl isothiocyanate; gentisic aldehyde; diethylphosphine; 1,2,4,5-tetrahydroxybenzene; 2,5,4′-triethoxydiphenyl-1-diazonium chloride; cis-propenyl bromide; 2,4,2′,4′-tetrohydroxydiphenyl; anthracene-9,10-dicarboxylic acid.

Richard M. Hewitt, chairman of the **American Medical Writers' Association** educational committee, has announced that there is a great **need for $500 scholarships** to support students wishing to enroll in the newly organized courses in medical editing and writing that are available at the Universities of Missouri, Illinois, and Oklahoma. Interested persons should communicate with Dr. Hewitt, Section of Publications, Mayo Clinic, Rochester, Minn.

Book Reviews

A History of Mechanical Inventions. Abbott Payson Usher. Harvard Univ. Press, Cambridge, Mass., rev. ed., 1954. xi + 450 pp. Illus. $9.

One might expect that the author of a comprehensive treatise on the history of mechanical inventions would be a professor of mechanical engineering, so engrossed in his subject as to delve deep among its hidden foundations. But while the professorial rank attributed to the author of this excellent book proved to be correct, it turns out (although this is not disclosed on the title page) that Usher is professor emeritus of economics at Harvard, with a very pronounced liking for history. But I think many of his readers will agree with me that with a little encouragement he might have become an engineer.

The book is in fact a revised and enlarged edition of an earlier work by the same author published in 1929 under the same title. The first four chapters present entirely new material. Their titles, in order, are "The place of technology in economic history"; "Historical analysis of social change"; "The particular system of events"; and "The emergence of novelty in thought and action." They are designed to provide the reader with a systematic statement of the philosophic and psychological theory that guided the author in the preparation of the descriptive and narrative chapters. As such, they should also be of interest and assistance to historians engaged in other fields. But they are not easy reading, and many readers will early be inclined to take the author's word for it and jump to the juicier chapters that follow.

These later chapters present to the student of mechanical inventions an intriguing story, with a wealth of detail, supplemented by many drawings and richly documented. They include the mechanical equipment of pre-Christian antiquity; water wheels and windmills; water clocks; mechanical clocks and their development into instruments of precision; printing; textile machinery; machine tools and quantity production. With the exception of the last chapter on the production and distribution of power, the historical account ends at 1850 and usually earlier. To me the transcendent chapter of all is the one devoted to Leonardo da Vinci, engineer and inventor.

It is of interest to note that photographic typesetting has been employed in producing this book. The result is pleasing, and it is fitting that the book itself should exemplify a new invention.

LYMAN J. BRIGGS
Director Emeritus, National Bureau of Standards

The Physics of Experimental Method. H. J. J. Braddick. Wiley, New York, 1954. xx + 404 pp. Illus. $7.

Now that it is no longer practicable, with the increased enrollments in physics, to have undergraduates make minor repairs on their equipment or to design and build apparatus for their experiments, many colleges have introduced courses in laboratory arts. Braddick gives such a course at the University of Manchester entitled "The physics of experimental method." This book, bearing the same title, was written for the course. It is not and was not intended to be a source book for the student looking for detailed procedures and techniques. The course for which it was written is a lecture course, and, as the title indicates, it is primarily concerned with basic physical principles as they apply to experimental work. However, references to original sources and to other books are given so that the details of procedures may be found.

The student will find the chapters on "Errors and the treatment of experimental results," "Mechanical design," "The natural limits of measurements," and "Electronics" particularly valuable. This last chapter is for those who have not had a course in circuitry. The chapter on "Mechanical design," which deals with degrees of freedom, hysteresis, optimum size, and vibration, is especially well done and covers a field neglected by most teachers.

Those who have had a course in light will find little that is new in the chapter on optics, and most students will be disappointed that the chapter on nuclear physics is so brief. My chief criticism of the book is that too many items are discussed too briefly. For example, three pages are devoted to electric motors and three to vacuum gages.

This book is recommended for courses concerned with the broad aspects of experimental investigation. For courses emphasizing a particular area—for example, nuclear physics—and for those designed to develop manipulative skills, it should be available, and perhaps required, for supplementary reading.

V. E. EATON
Department of Physics, Wesleyan University

The Microtomist's Formulary and Guide. Peter Gray. Blakiston, New York, 1954. xiii + 794 pp. Illus. $10.50.

This is a valuable source and reference book for anyone who is concerned with the preparation of biological materials for microscopic examination. Numerous books on histologic technique are available, but not one of them written in English is equal to this work in logical organization and comprehensiveness.

There are 28 chapters. The first 16 chapters deal with the preparation of microscope slides. Chapters are devoted to whole mounts, smear and squash preparations, ground sections, paraffin, nitrocellulose, frozen sections, and methods utilizing injection masses. The chapters are well illustrated. Many of the drawings and much of the text of these first 16 chapters are to be found in the author's *Handbook of Basic Microtechnique.*

The last 12 chapters, which comprise more than two-

thirds of the book, contain methods and formulas for 3500 histologic preservative, fixative, staining, mounting, and miscellaneous procedures. These are grouped according to a decimal classification. Each chapter begins with an outline of its contents. The directions are considerably condensed by the uniform use of the metric system, with the solutions adjusted generally to give 100 parts, except for the fixatives which are adjusted to give 250 parts.

A discussion of the more important methods is included, and practical applications are frequently given. Literature references appear to be complete.

It is unavoidable in a book of this type that many procedures of purely historical interest are included. Perhaps the book will serve to revive some of the beautiful techniques that were the pride of the older microscopists but which are unsuited to the modern mass production of slides.

The Microtomist's Formulary and Guide shows an almost deliberate avoidance of histochemical methods. Even the Prussian blue procedures, which have been used by biologists for almost a century, are excluded.

This book should be a part of the library of every serious histology laboratory.

FRANK B. JOHNSON
Armed Forces Institute of Pathology, Washington 25, D.C.

Instrumental Analysis. John H. Harley and Stephen E. Wiberley. Wiley, New York; Chapman & Hall, London, 1954. vii + 440 pp. Illus. $6.50.

This book aptly fills a very definite need. The tremendous increase in instrument methods of chemical analysis has called for just this type of treatment. The authors discuss both the theory and applicability of practically all currently used instrument techniques. Sufficient theory is given so that a clear-cut understanding of the principles of a method is possible. Copious literature references are included for the reader who seeks more detail, but the treatment in this book is adequate for most purposes.

It is refreshingly up to date and supplies the reader with pertinent information on specific commercial instruments now on the market. Of course it is inevitable that some of the information given no longer holds true, but that is the penalty paid for completeness. I would have liked to have seen some reference to the use of the pressed-disc KBr technique in infrared because of its importance and usefulness, but perhaps this is expecting too much since it is only a year or so since this technique was introduced.

In general the authors have brought the latest developments in each of the fields discussed to the fore, and they are to be commended on the clarity of their presentation. This book should be useful not only to the practicing analytic chemist, in giving him both the fundamental principles involved for new techniques and sufficient practical know-how so that he can make use of a method, but it should be of even greater value to the nonanalytic chemist in giving him, under one cover, the theory and power of the newer analytic techniques and sufficient information to enable him to make a good estimate of the probable applicability of a specific technique to a specific problem.

The instrument techniques that are discussed include visible, ultraviolet, and infrared spectrophotometry; Raman and emission spectroscopy; fluorometry; flame photometry; colorimetric *p*H, potentiometric, conductimetric, amperometric, and high-frequency titrimetry; polarography; x-ray and mass spectrometry; and, of course, radiotracer techniques. A chapter on practical experiments is included to serve for a college laboratory course. This is an excellent treatment, remarkably brief and clear, of a complex field of science.

H. A. FREDIANI
Process Research and Development Division, Merck & Co., Inc.

Adhesive Bonding of Metals. George Epstein. Reinhold, New York, 1954. ix + 218 pp. Illus. $2.95.

It is probable that relatively few people are aware of the increasing extent to which industrial adhesives are being used as substitutes for rivets, bolts, weldments, and other conventional methods of fastening metal parts together. The author states:

> It is the purpose of this book to give sufficient details so that an engineer or technician, faced with the problem of joining two materials, will be able to determine if an adhesive bonded joint would be advantageous, what type of adhesive to select, how to employ the adhesive and how to design the joint for optimum performance.

All things considered, the book comes surprisingly close to achieving this rather ambitious goal.

After an introductory chapter discussing the advantages of adhesive fastening, with perhaps insufficient attention to the disadvantages, the chemistry of the basic materials is reviewed. The real meat of the book is contained in three valuable and lucidly written chapters dealing with the problems of formulation of metal adhesives, design and testing of adhesive joints, and bonding techniques.

The roles and effects of the various ingredients in the formulation of adhesives are discussed extensively, and examples are given. Emphasis is placed on thermosetting structural (high strength) adhesives. In the chapter on bonding techniques, emphasis is placed on the very important step of surface preparation, and detailed instructions are presented for the optimum mechanical and chemical surface treatments for many metals and alloys.

Two briefer chapters are devoted to heat-resistant adhesives and adhesively bonded metal sandwich structures. The author has drawn extensively on the growing applications in the air-frame industry for most of the many illustrative examples.

The book is not without faults. The tyro is not warned of the difficulties that may be encountered because of adsorption of moisture. The second chapter, dealing with the chemistry of adhesives, will un-

doubtedly be of small value to most engineers (unless they are chemists as well) and may indeed overwhelm many. The chapter assumes a knowledge of terms such as "esterification," "polymerization," and "alkyl and aryl radicals," but in a later chapter the reader is cautioned regarding the proper method of diluting strong acids. The list of selected references appears to be rather insufficient for the persons to whom the book is directed.

W. E. TAYLOR

Motorola Inc., Phoenix, Arizona

The Design and Use of Instruments and Accurate Mechanism. Underlying principles. T. N. Whitehead. Dover, printing 2, New York, 1954. xiv + 283 pp. Illus. Paper, $1.95; cloth, $3.50.

This second printing of a useful book that appeared originally in 1934 contains a new preface and minor corrections by the author. Instrumental errors are discussed in part I and the theory of instrumental errors that is developed in part I is applied, in part II, to a variety of typical mechanisms. Selected so as to illustrate principles, all examples are fully explained.

Spot Tests. Fritz Feigl. Trans. by Ralph E. Oesper. Eng. ed. 4 in 2 vols. vol. I, *Inorganic Applications,* xii + 518 pp. $6.50; vol. II, *Organic Applications,* xv + 436 pp. Illus. $6.25. Elsevier, Houston–Amsterdam, 1954.

There are some scientists who have devoted themselves so assiduously and unreservedly to particular subareas of chemistry that their names are practically synonymous with those areas. One such individual is Fritz Feigl, who by his large number of papers and books on the subject has identified himself with that technique of microchemical qualitative analysis known as spot tests. A new book or a new edition of an old book by Feigl is usually a good indication of the current status of the development and applicability of spot tests.

In his 1949 book, *Chemistry of Specific, Selective and Sensitive Reagents,* Feigl attempted to collect the material pertinent to the physical-chemical basis of spot tests. The present work, which deals exclusively with the application of spot tests, actually consists of two separate monographs, since the chapter on spot-test techniques, written by Philip W. West, is given in both volumes.

The format used in previous editions for the description of individual tests and procedures has been retained; an introductory section of one or several paragraphs on the basic chemistry of the reactions involved is followed by a succinct laboratory procedure. Then follow statements of the absolute limit of detection, the concentration limit, and the reagents required. Comments on interferences, possible modifications, and so forth, are then often given. A helpful device is the statement at the bottom of each page of the location in the text of the references cited on that page.

To save space, the bibliography of papers on the technical application of spot tests that was contained in previous editions has been omitted. On the other hand, the material on preliminary tests and on the possible technical application has been enlarged. Much heretofore unpublished material by the author and his coworkers is included, especially on the application of known tests of organic qualitative analysis to spot-test technique, as well as on the development of new tests suitable for organic substances.

The author stresses the fact that the material has been presented so as to allow the ready conversion of the tests to a macro scale as well as to apply the principles involved to chromatography and, in particular, to paper chromatography.

The material should be readily comprehended by the advanced undergraduate student who has had courses in organic and analytic chemistry, although the book is not a textbook but rather an annotated laboratory manual. One or both of the volumes would be helpful references to anyone concerned with rapid qualitative analysis, for example, biochemists, mineralogists, and so forth, particularly when only minute amounts of the sample are available.

The translation by Ralph E. Oesper is of the high quality characteristic of his translations. English-reading chemists are deeply indebted to Oesper for the labor he has expended in translating papers and books of interest, not only in analytic chemistry, but also in the history of chemistry.

The two volumes are well printed and seem free of serious typographical errors. The binding, however, is not of comparable quality. The price seems quite reasonable.

PHILIP J. ELVING

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Semimicro Qualitative Analysis. Edwin O. Wiig, Willard R. Line, and John F. Flagg. Van Nostrand, New York, rev. ed., 1954. viii + 238 pp. Illus. $3.25.

This textbook is an almost completely rewritten version of the original Flagg and Line *Semimicro Qualitative Analysis.* The theoretical section consists of eight chapters which deal with "Structure of matter," "Solutions," "Chemical equilibrium," "Applications of chemical equilibrium to homogeneous and heterogeneous systems," "Complex ions," "Amphoterism," and "Oxidation-reduction." An elementary but effective consideration of the factors involved in the solubilities of ionic compounds is included in Chapter 2. Several applications of the Nernst equation to the calculation of several types of equilibrium constants from the emf of cells are a unique feature of Chapter 8.

The experimental section includes discussions of semimicro techniques and the procedures to be used for the analysis of the ions of 22 metals and of 17 anions. The cations are classified into the five standard groups, with hydrogen sulfide being used as one of the reagents in the separation of groups II and III. The anions are classified into the volatile acid,

chloride, sulfate, oxidizing, and reducing groups. Notes adjoining the procedures point out the application of the theory of ionic equilibriums to the various separations and identifications encountered. Preliminary experiments on the properties of ions are omitted to allow more time for the analysis of "knowns" and "unknowns."

An adequate selection of problems follows six of the chapters on theory, and a set of general questions on the analytic procedures is placed at the end of the experimental section. The appendix contains four tables of equilibrium constants, a four-place log table, and answers to the numerical problems. Some of the values of equilibrium constants are not in agreement with some of the recently published values of Latimer and his colleagues.

The semimicro scale used involves, in general, volumes from 0.2 ml to 10 ml and weights from 1 to 25 mg.

This textbook seems to be appropriate for either the latter portion of a first-year college course or for a separate course in the sophomore year. A section on special procedures for ferro- and high-aluminum alloys may be used to provide additional analytic experience with several cations not usually included in the qualitative analytic scheme.

LLOYD E. MALM
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Isotopic Tracers. A theoretical and practical manual for biological students and research workers. G. E. Francis, W. Mulligan, and A. Wormall. Athlone Press, London; John de Graff, New York, 1954. xvi + 306 pp. Illus. $7.

Although many excellent books dealing with isotopes are available, it is generally recognized that there exists a real need for a practical laboratory manual in this field. *Isotopic Tracers* is presented as such a manual and is, according to the authors, a full description of the course that they have given, over a period of several years, at the Medical College of St. Bartholomew's Hospital, London.

The book is divided into two parts. Part one, "Theoretical considerations," comprises approximately two-thirds of the volume. There is little in this section that cannot be found in a number of books previously published. Its chief advantage lies in its simplified and condensed presentation, which may be more palatable for students and beginners in the tracer field. Part two, "Practical course," contains detailed presentations of classroom experiments. Typical experiments are: the use of G.M. tubes for measurement of radioactive isotopes; the determination of atom percent excess N^{15} in a sample; incorporation of P^{32} into hen's eggs; calculation of circulating red-cell volume and blood volume based on persistence of injected P^{32} labeled red cells; localization of injected I^{131} in the thyroid; and determination of self-absorption curves. It is this second part that makes the book unique in its field. This part should prove extremely useful to the teacher in planning laboratory assignments and to the research worker as a manual for the indoctrination of newcomers to his laboratory into the proper use of isotopes.

A serious criticism of *Isotopic Tracers* is its limited presentation of C^{14} techniques, which play a most important part in biological applications of isotopes. No laboratory experiments with C^{14} are presented nor is any mention made of the windowless gas-flow counters that have become standard equipment for C^{14} assay, at least in the United States.

SIDNEY UDENFRIEND
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National Heart Institute,
National Institutes of Health, Bethesda, Maryland

Industrial Stoichiometry. Chemical calculations of manufacturing processes. Warren K. Lewis, Arthur H. Radasch, and H. Clay Lewis. McGraw-Hill, New York–London, ed. 2, 1954. xi + 429 pp. Illus. $7.50.

One of the early courses in the traditional chemical engineering curriculum deals with the analysis of process data through computations based on the laws of mass and energy conservation and chemical combination. A considerable portion of the chemical engineers in this country have cut their professional teeth on *Industrial Stoichiometry* by Lewis and Radasch. The second edition of this book is a completely revised text that retains the purpose and pedagogic viewpoint of the original version.

The case method is again used in developing and illustrating computational procedures. Combustion problems involving gaseous and liquid fuels serve to introduce techniques which are later extended to cases dealing with solid fuels, secondary fuels, and various inorganic chemicals. New chapters on nitrogen compounds, fixed alkalies, and ceramics are included. The material on equilibrium, sulfur, lime and cement, metallurgy, and design has been expanded considerably. In addition to the illustrative examples in the text, a total of 171 problems are included at the ends of the chapters. The problems are largely graded, and answers are indicated in a few instances.

The authors have clearly pointed out some of the problems encountered in analyzing industrial processes and evaluating experimental data. In general, however, the textbook is not meant to describe the whole process of which an illustrative operation or unit is a part. The consideration of energy balances is limited to cases in which the net enthalpy change of the system is equal to the quantity of heat exchanged with the surroundings. A more extensive discussion of energy relationships would be desirable.

As stated in its preface, the book is directed toward plant operating personnel and students just beginning their study of chemical technology. Knowledge of calculus and advanced chemistry is not necessary. The book is well written, but the reader's impression of its clarity and continuity will probably be determined largely by his reaction to the case method of instruc-

tion. In particular, some teachers of chemical engineering will feel that the evolution of separate cases obscures general principles and encourages memorization of distinct techniques. Other teachers who have used the original edition successfully will welcome the expanded coverage of the second.

ROBERT R. ROTHFUS
Department of Chemical Engineering,
Carnegie Institute of Technology

Induction and Dielectric Heating. J. Wesley Cable. Reinhold, New York, 1954. vii + 576 pp. Illus. $12.50.

The author may be justly proud of his lucid and comprehensive interpretation of the fundamentals and the engineering phases of induction and dielectric heating. This work conveys a historical and technical panorama of the art and practice with such clarity that it is an excellent reference for the student and practicing engineer, and a highly functional guide for the technical and nontechnical members of industry who are associated with these forms of heating.

In reality this work comprises two basic subjects, induction heating and dielectric heating. While the two subjects are treated separately, frequent cross references point out the similarities and dissimilarities between the two types of heating, and demonstrate the advantages and disadvantages of each form. The engineering principles are competently discussed, and the theory is conveyed to the reader over a bridge of analogies for rapid digestion. The book is sprinkled with a number of pertinent graphic relationships that enhance the understanding of the subject matter and provide useful design data. The author is to be commended for selecting and furnishing only those equations germane to the comprehension and application of the science. Writers often succumb to the temptation to encumber their work with numerous mathematical or physical relationships with an apparent effort toward erudition but with wanton disregard of the real function of the text, which is to convey information accurately and directly.

Following the summary of the technical aspects of the art, Cable reviews the sources of energies available. This survey provides valuable engineering information on the various means of generating the high-frequency power necessary. The author's skill is again revealed by his ability to draw the reader's attention to such technical or economic facets of the equipment that are pivotal in determining its practical qualifications. To illustrate, in the discussion of the effects of bus voltage variations upon electronic generators, he presents pertinent graphs demonstrating the effect of filament voltage variations on the emission and life characteristics of an oscillator tube. Although this information, per se, is not unusual, it is a valuable help in determining the economic feasibility of electronic power supplies in plants suffering a certain degree of voltage variation.

Coil and electrode designs in large part determine the effective application of induction and dielectric heating, respectively, and the two chapters devoted to this phase of the art provide a very adequate background and guide for solving the design problems encountered.

The major part of the book is devoted to the application of induction and dielectric heating in industry and laboratories. This coverage presents a very thorough and comprehensive treatment of various industrial and other specialized uses of high-frequency electric heating. Its completeness, in fact, is extended to include speculation on the future potentialities of dielectric heating. The number of illustrations is ample, and they add significantly to the understanding of heating problems and applications.

The completeness of this book is further attested by the inclusion of a discussion of radio interference produced by the operation of the high-frequency electric heating equipment. I feel that *Induction and Dielectric Heating* is a valuable adjunct to the libraries of the designer and of the application engineer.

EMANUEL L. BRANCATO
Solid State Division,
Naval Research Laboratory, Washington 25, D.C.

Nuclear Reactors for Industry and Universities. Ernest H. Wakefield, Ed. Instruments Publ., Pittsburgh, 1954. ix + 93 pp. Illus. $2.

This brief book has three very timely and worthwhile objectives: (i) to call attention to the fact that small research-type reactors are now at such a stage of development that any large university or industry should be able to afford one; (ii) to stimulate and encourage the widespread use and further development of research reactors by universities and industry; and (iii) to present in compact form information that will "aid universities and industries in making decisions about the installation of reactors."

The first objective is well supported by a summary of a cost estimate prepared by Henry J. Gomberg and colleagues at the University of Michigan. It indicates that $370,000 will cover the cost of reactor and tank for a modified "swimming pool" arrangement, including operating necessities and safety instrumentation but exclusive of fuel, which must be obtained by arrangement with the Atomic Energy Commission. To this must be added the cost of the building ($60,000 to $300,000) and of the laboratory research facilities for which some sketchy estimates are indicated.

The second objective is supported by a stimulating preface by K. S. Pitzer and by a very brief analysis of the value of a research reactor, which would well merit broader consideration and treatment than that allotted to it.

Four chapters of elementary, semipopular, technical information about reactor classifications, control, instrumentation, and radioactive measurements, one chapter on radiation protection, and one chapter on legal aspects, are intended to support the third ob-

jective. Any university or industry capable of justifying an outlay of approximately $500,000 for a research reactor will certainly have on its staff one or more capable scientists who need and can make good use of a research reactor. These scientists, who will play an important part in justifying any decision to acquire a reactor, will find the technical information disappointingly elementary and of little assistance. Supporting references to the literature are not adequate to compensate for this deficiency.

The chapters on legal aspects and radiation protection are more helpful, because they present less commonly known but necessary information in condensed form, and these chapters place a very appropriate stress on the serious, important considerations of adequate radiation safeguards.

It is important at this time that extensive use and improvement of research reactors be stimulated. This book represents a timely step in the right direction, but falls short of meeting the need. It will perhaps best serve by stimulating the interest of nontechnical people.

R. D. HUNTOON
National Bureau of Standards, Washington, D.C.

A Text-Book of Macro and Semimicro Qualitative Inorganic Analysis. Arthur I. Vogel, Longmans, Green, New York–London, ed. 4, 1954. xv + 663 pp. Illus. + plate. $4.50.

This excellent volume represents an extension and modernization of the third edition (1945). In the first chapter (a long one) the author presents a very thorough coverage of all the background theory required for qualitative analysis and a large amount applicable to quantitative analysis as well. Many numerical problems are worked through in detail, and the Brönsted-Lowry treatment of acids and bases is used and applied to the hydrated ions of salts. Activity coefficients and their applications are briefly discussed.

Semimicro and macro techniques are thoroughly discussed in the second chapter, which contains many illustrations of apparatus and their use. In particular, attention might be called to page 187, which contains a nicely balanced photograph of all the semimicro apparatus needed by the student. Following this are chapters on reactions and analytic procedures for cations and anions, including the use of organic reagents. For the latter, sensitivity and concentration limits are given. One might wish that the molecular equations used in these chapters had been replaced by ionic equations, but the former were probably retained to conserve space (the author asks the student to use ionic equations in his notebook).

Chapter 5 does not seem to be needed, for it is given over to systematic macro qualitative analysis for elementary students, and the same material is extended and developed in Chapters 6 and 7, dealing with systematic qualitative inorganic analysis; separations are made conventionally with hydrogen sulfide. Later chapters deal with procedures for the removal of interfering organic acids, silicates, borates, fluorides, and phosphates. A comprehensive chapter on the chemistry of the less common elements is followed by a very useful though short chapter on paper chromatography and its application to group separation and identification of ions by R_f values.

The author is head of the chemistry department, Woolwich Polytechnic, London, but the book appears to have been written in the hope that it would find service in American schools as well as British. Names and addresses of manufacturers of instruments, both in the United States and in Europe, are often given, occasionally, with the advantages or disadvantages of one make over the other. British spelling is used throughout, and American teachers considering the book for adoption will have to consider this feature, along with the European convention (opposite sign) used in electrode potentials (this is not to say that all American authors are in agreement on this point). Opposed to these features is the obvious fact that the book appears eminently teachable, and that any student familiar with this work will have a very sound background in inorganic and analytical chemistry.

EVANS B. REID
Department of Chemistry,
The Johns Hopkins University

Laboratory Instruments. Their design and application. A. Elliot and J. Home Dickson. Chemical Publ., New York, 1953. 414 pp. Illus. $7.50.

This book consists of 16 chapters that cover in a limited way some of the problems of instrument building. Most of the chapters are only a few pages long; the authors devote most of the space to glass and optics. The chapter on glass contains more generally useful information than is usually found in one place. An attempt is made to include United States trade names for glasses and glass-working compounds. The chapter on lenses, mirrors, and prisms is so condensed that it is difficult to use without considerable prior knowledge of the subject. The numerous illustrations of lens, mirror, and prism arrangements, as well as tabulations of the properties of some types of lenses, could well be a source of "suggestion" to a designer of an instrument requiring a few optical parts. The treatment of subjects other than optics is superficial, and at times hardly more than a statement that the subject matter exists. The bibliography is principally of articles available only in Great Britain or in large United States libraries. British names, such as screw head, would be confusing to United States designers. The book as a whole is hardly a complete enough discussion of laboratory instruments to be useful for either instruction or reference.

DONALD E. WILLIAMSON
Williamson Development Co.,
West Concord, Massachusetts

Technical Papers

Paper Chromatography for Identifying Air Pollutants

Bernard D. Tebbens and Jack D. Torrey

School of Public Health,
University of California, Berkeley

During the first months of 1953, six samples of particulate material in outdoor air were obtained by filtration to determine the efficacy of paper chromatography for detecting pollution components. This preliminary report indicates a possible use of a relatively simple microanalytic tool for that purpose. Of greater interest is the accrued evidence that a derivative of acetic or formic acid in particulate form is characteristic not only of the San Francisco Bay Area air pollution but also of the effluent gases of several types of combustion.

The air-sampling station was on the roof of a three-story campus building. Samples of particulate material were obtained by drawing a large volume of air on each of 6 days through 15-cm circles of Whatman No. 40 filter paper. Figure 1 shows sample volumes and the resulting paper darkening caused by air contaminants. Since a preliminary interest concerned the possible presence in the contamination of lower fatty acids, a chromatographic method of Kennedy and Barker (*1*) was adopted.

In preparation for chromatography, the filters were extracted with dry ether, in some cases in a soxhlett apparatus, in others by overnight steeping at room temperature. The ether extracts were evaporated at room temperature to 15 ml, and then made to 25 ml with ammonia-saturated ether. This solution was evaporated to a small volume for application to the paper.

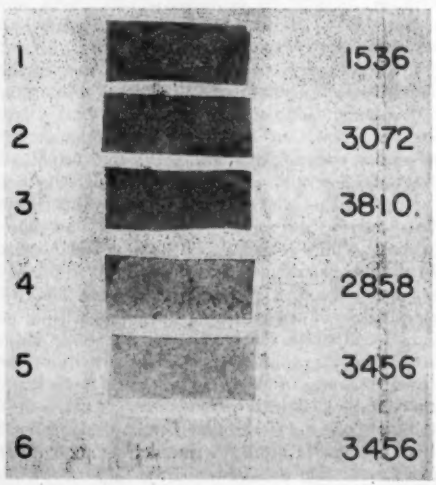
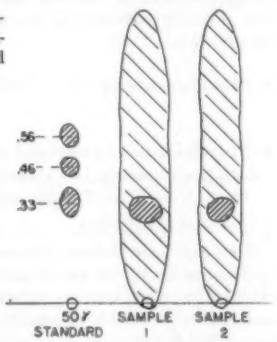


Fig. 1. Portions of Whatman No. 40 filter papers on which aerosol samples were obtained, each on a different day during daylight hours. The samples are numbered at the left; their volume (ft^3) is shown at the right. Samples 1 and 2 were taken in January, samples 3 and 4 in March, and samples 5 and 6 in May.

The developing liquid was 95 percent ethyl alcohol, containing 1 ml per 100 ml of aqueous ammonia. After developing the samples by the ascending technique on Whatman No. 1 paper, the paper was dried for about 1 hr in air and then sprayed with the bromphenol blue indicator described by Kennedy and Barker (*1*).

With each sample, a standard containing equal weights of formic, acetic, propionic, and normal butyric acids as the ammonium salts was developed. Using as little as 20 μg of the mixed standard, a separation of the several acids was obtained, except that formic- and acetic-acid spots nearly coincided at R_f 0.31 to 0.35. Figure 2 is a sketch of the separation achieved with samples 1 and 2.

Fig. 2. Sketch of developed chromatogram. Elongated comets show spread of fluorescence.



In samples 1 to 4, acetate or formate was present. From spot-size comparison, the air concentration of equivalent acetate was estimated as follows: sample 1, 1 $\mu g/m^3$ of air; sample 2, < 0.5 $\mu g/m^3$; sample 3, < 0.5 $\mu g/m^3$; and sample 4, < 0.5 $\mu g/m^3$.

In no sample was an acid radical higher than the acetate detected. Under ultraviolet light an unidentified fluorescing material, in addition to the acid, appeared in each sample. Distribution of this fluorescence, which persisted 1 yr later, is indicated in Fig. 2. No acid was found in samples 5 and 6, although some fluorescing material was noted. These two samples, and especially sample 6, were appreciably less dark than the others (*2*).

Thus, a lower fatty-acid radical, detectable by chromatography, was present in several characteristic air-pollution episodes (*3*). This suggests that a relatively simple method of determination may be used to define the presence or absence of "smog." Reduction of visibility is not necessarily a criterion, since such an effect may be simply the result of water condensed on normally present nuclei.

It did not seem likely that either acetate or formate

was present as the relatively volatile acid. Several laboratory experiments were run, filtering concentrations of acetic-acid or formic-acid vapor, readily detectable by odor, through Whatman No. 40 filter paper. In no case was acid recovered from the filter paper treated in the same manner as described previously. This was true even when carbonaceous smoke, made by incomplete combustion of benzene, was present in the mixture that was filtered.

It is possible that the acid radical found in the air samples was in the form of fine particles of one or more salts. Several acetates, including those of lead, calcium, sodium, copper, and magnesium, were prepared individually in solutions such that 0.1 ml contained 50 μg of acetate. Each of these preparations was evaporated to dryness and then taken up in ether saturated with ammonia, the latter solution being treated by the same chromatographic technique. In each case, nearly quantitative separation of acetate was achieved by spot-size comparison with a known standard solution. This indicates that any one of several acetate salts could have been present in the air samples and identified by the analytical procedure employed.

Since combustion seemed a possible source of the acid component detected in polluted air, the cooled gases from a number of combustion processes were sampled by filtration, either with Whatman No. 40 filter paper or with double-thickness extraction thimbles. The filters were dried at temperatures up to 100°C before analysis.

The gases thus sampled included engine exhaust of a relatively new automobile operating at idling speed (61 ft^3, showing only a trace of carbon); stack gas from an incinerator burning sawdust and a small amount of biological residues at a high temperature (10 ft^3, showing negligible free carbon and some finely divided fly ash); flue gas from a 75,000 Btu/hr natural-gas furnace (20 ft^3, showing no trace of carbon); and stack gas from a wood-burning fireplace (20 ft^3, showing appreciable carbon). From each of these combustion sources particulate acetates or formates were chromatographically separated in the following relative amounts: automotive exhaust, < 300 $\mu g/m^3$; incinerator, < 300 $\mu g/m^3$; gas fire, < 3000 $\mu g/m^3$; wood fire, > 3000 $\mu g/m^3$. There was no acid higher than acetic in any of the samples. Additionally, 18 ft^3 of natural gas contained no filterable acetate or formate. From each of these sources, except raw natural gas, a fluorescent, oily material was also extracted.

Because of the close approximation of the developed spots for formic and acetic acids, it cannot be said absolutely that all of the acidic material was one or the other. The spots found were at R_f 0.31 to 0.35. The data of Kennedy and Barker (*1*) show only acetic and formic acids at these low R_f values. Some additional data for the same type of analysis by Nair (*4*) indicate that a number of alkoxy acids are also at higher R_f values than 0.35. Thus, the substances filtered out of polluted air and determined by the procedure described are particulate one- or two-carbon acid radicals. Similar components are present in the effluent gas from combustion of several solid, liquid, or gaseous fuels. Additionally, it is probable that combustion in some cases is accompanied by synthesis of a small amount of the nonvolatile oil aerosol that was noted as fluorescent material on the chromatograms.

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2. On all sampling days, chosen because of visible haziness, the absolute and relative humidity was low, and the temperature was higher than ordinary. Records from two nearby stations show that wind velocities averaged less than 5 mi/hr except during the day of sample 6 when it was about 10 to 12 mi/hr.
3. J. D. Torrey has recently observed both lower fatty acid and fluorescent oil in a sample of filtered air from Denver, Colo.
4. J. H. Nair, *Anal. Chem.* **25**, 1912 (1953).

30 August 1954.

Homogenizer for Continuous Homogenization

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In connection with the preparation of alkaline phosphatase from the microsome fraction of intestinal mucosa (*1*), it was desired to prepare homogenates in larger quantity than could be conveniently obtained with the conventional Potter-Elvejhem homogenizer. Consequently, a modification was made to permit a continuous passage of the material through the homogenizer.

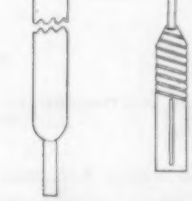

Fig. 1. Components of modified Potter-Elvejhem homogenizer.

The modified homogenizer is illustrated in Fig. 1. The barrel was constructed from a 25-mm Pyrex ignition tube, with a 10-cm length of 10-mm tubing sealed on one end to provide the outflow tube. The neck of a 250-ml Erlenmeyer flask was sealed to the other end of the ignition tube, and the bottom of the flask was removed to provide a reservoir for the material to be homogenized. The inside of the barrel was ground with a metal lapping tool and Alundum powder until the

walls were parallel as indicated by uniform stippling.

The pestle of the homogenizer was constructed of a 1-in Lucite rod 4 in. long, threaded at one end to receive a ¼-in. stainless-steel shaft. The shaft was of sufficient length to clear the reservoir by 2 in. with the pestle in position. The Lucite rod was turned down on the lathe to a diameter 0.001 in. less than that of the barrel. Eight turns of a four-to-the-inch left-hand thread were cut into the pestle, and four grooves 1/16 in. deep were cut longitudinally from the middle of the pestle to within ½ in. of the lower end. The threads and grooves were cut with a round-ended tool so that there would be no sharp angles into which the homogenate could pack. The top ¾ in. of the pestle was tapered outward from the stainless-steel shaft. Finally, the pestle was ground in with 220-mesh Alundum to give a loose fit (0.002 to 0.003 in. clearance).

In use, the barrel was held rigidly in a vertical position, and the shaft of the pestle was connected by a length of rubber pressure tubing to a suitable stirring motor. The tissue to be homogenized was minced and suspended in two volumes of the homogenizing medium. For intestinal mucosa, 5 sec in the Waring Blendor gave a suitable suspension. The suspension was then passed through the homogenizer at a rate of 600 ml in 30 min. In order to obtain adequate homogenization, two more passages through the homogenizer were required, after which microscopic examination indicated 70 to 90 percent disruption.

The homogenizer is obviously susceptible to considerable modification in size and detail, and could readily be jacketed for cooling. In addition to the work with mucosa, it has also been useful in preparing large volumes of liver homogenates (*2*).

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19 July 1954.

New Stereotaxic Instrument for Use with the Rat

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Since the original development of a stereotaxic instrument by Horsley and Clarke, a number of different devices for placing lesions within the brain have been described for use with monkeys, cats, and rats (*1–5*). Nevertheless, many fundamental difficulties remain in their use, particularly with the rat. The present development provides an instrument for use with the rat (*6*) that would offer maximal stability, accuracy, and ease of operation.

The following are the major advantages of the instrument described here (Fig. 1). First, the 10- by 30-cm platform *A* to hold the animal is mounted on two racks to permit movement of the animal forward and back or left and right under the active electrode. This procedure eliminates the need for racks or slides above the head of the animal, and thus simplifies the construction of the electrode carrier; more important, it gives clear and unobstructed access to the operative field. By moving the platform, the animal can be placed anywhere under the active electrode over a range of 5.0 cm in the anterior-posterior direction and 4.0 cm in the left-right direction.

The second, and perhaps most noteworthy, advantage, is the construction of the electrode-carrier assembly. The entire carrier is mounted on a movable post *B* attached to the base of the apparatus 18 cm in front of the ear bars. This post can be swung aside so that the head of the animal is fully exposed to the operator. When coordinates are to be determined or the electrode is to be placed, the post can be swung back and locked into position, leaving the electrode zeroed over the head of the animal. The electrode itself can be adjusted in four ways: (i) the electrode carrier *C* can be moved vertically by a rack-and-gear arrangement over a range of 5.5 cm; (ii) it can also be adjusted over a 90° arc *D* in the anterior-posterior plane, giving any angular approach from 45° posterior to 45° anterior; (iii) this anterior-posterior arc, holding the electrode carrier, is in turn attached to a circular rack *E* that permits angular adjustments in the left-right plane, 50° each way; (iv) the post supporting the entire carrier assembly can be moved up and down on a screw *F* over a range of 3.5 cm, and thus allows a second vertical adjustment of the active electrode.

With these four adjustments, the active electrode can be brought directly to any target structure within the brain from any angle. The principle involved is simply to make the target the center of the hemisphere described by the anterior-posterior and left-right arcs. Then, whenever the electrode-carrier is returned to zero, the tip of the active electrode will always be on the computed target, regardless of whether the approach is from a simple or a compound angle or is perpendicular to the brain.

The procedure is simple. When the active electrode is at the correct anterior-posterior and left-right coordinates above the target, the post is elevated far enough on its screw to allow the electrode to be set at zero and still clear the animal. The post is then lowered on its screw until the tip of the electrode just makes electrical contact with the dry dura mater. To prepare for the penetration of the brain for a given distance in order to reach a particular target, the electrode is raised above zero in excess of that distance, and the post is lowered on its screw by exactly that distance. Then, no matter at what angle the electrode is placed, its tip will always reach exactly the same target within the brain when its carrier is returned to zero since the target is always zero, and zero is always the center of the sphere that can be described by all angular adjustments.

The angular adjustments afford two other advantages: (i) In different operations, different superstructures may be traversed on the way to the same target, thereby providing a control against incidental destruction of any particular structure in the brain above the target. (ii) They make it very convenient to reach targets on the mid-line without having the approach obstructed by the longitudinal sinus.

The active electrode is a wire of platinum and 10 percent iridium coated with glass, except for 0.5 mm of exposed tip. The glass insulation is achieved by heating the platinum wire to burn off the hydrogen for good fusion and then inserting it into a fine glass tube until a little more than 0.5 mm protrudes. The platinum and glass are then fused carefully in a tiny flame and a long, fine copper wire is soldered to the free end of the platinum. The electrode is then threaded through 1-mm glass tubing until 2 cm protrude, and it is secured to the glass holder by cement. Finally, the fused end of the electrode is ground by hand on a fine emery belt until it is sharpened like a pencil and only 0.5 mm of wire is exposed.

The chuck *G* holding the electrode is taken from an Eversharp automatic pencil, and it is mounted in the electrode carrier on a ball-joint. Once the electrode is in place, the chuck can be positioned on the ball joint until the tip has been zeroed precisely. Then the ball joint is clamped firmly. In this process of zeroing, the distance that the electrode protrudes from its chuck is also adjusted until its tip just makes contact with the true zero of the apparatus, located on the platform exactly in the mid-line between the posts holding the ear bars. An auxiliary zeroing point, well off to the side of the animal's head, permits adjustment of new electrodes while the animal is in the apparatus.

The current used to make lesions is supplied by a 45-v battery. An electronic current regulator permits the application of any current up to 5 ma for any duration without fluctuations due to accompanying changes in the resistance of the animal. The positive lead of the current source is jacked into the top of the carrier *H* to make contact with the fine copper wire soldered to the electrode. Thus the active electrode is an anode. The indifferent cathode is a brass rod, 3 mm in diameter, inserted rectally to complete the circuit.

The head of the animal is held in place primarily by means of ear bars *I* that slide in posts on the platform. The end of each bar has a small nipple *J* mounted on the wide taper of the head of the bar. To insert the nipples into the ears accurately, the ears are slit and the meatus exposed. By sliding the ear bars until their calibration marks show that they protrude equally from the posts, the animal can be centered under the electrode and secured in position when the bars are anchored by thumbscrews *K*. Then the nose of the animal is clamped between a bar *L* under the upper incisors and a clamp *M* over the nose. This nose-clamp assembly can be raised or lowered and moved anteriorly and posteriorly to adjust the animal evenly in the apparatus.

The final adjustment of the animal in the headholder is made by locating the bregma with the tip of the electrode. The bregma is the intersection of the

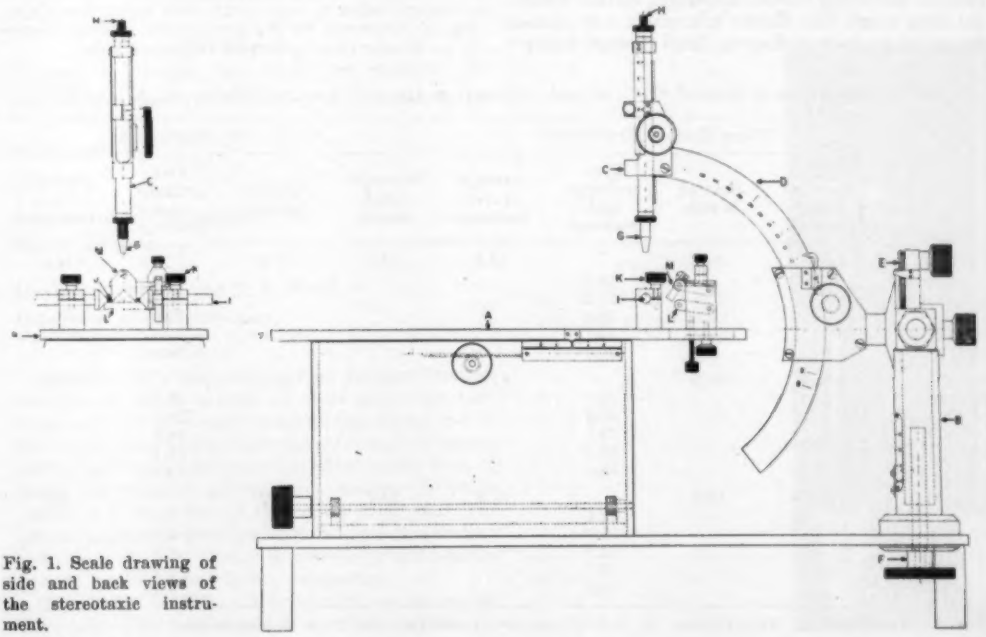

Fig. 1. Scale drawing of side and back views of the stereotaxic instrument.

frontal and sagittal sutures, and it is indicated on Krieg's atlas of millimetric sections of the rat's brain (*7*). Hence, it can be used as a reference point for the coordinates needed to reach any structure within the rat's brain.

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* Present address: Institute of Neurological Sciences, University of Pennsylvania Medical School.

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8 July 1954.

New Method of Presentation of Food Samples to the Hunter Color and Color Difference Meter

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In our attempts to establish the relationship between the color of processed fruit and vegetable products, as determined by the Hunter Color and Color Difference Meter (*1*) and the score given for color by the Agricultural Marketing Service inspectors, certain difficulties have arisen. The Hunter instrument only permits the use of products in discrete forms through multiple spot readings on the sample food product. These multiple readings are time consuming. To surmount this difficulty, some investigators (*2*) have presented a homogenized sample to the meter. This does eliminate the variation induced by the various angles and interstices of the product, but it also presents to the meter a product totally unlike that which is viewed by the Agricultural Marketing Service inspector or other observers.

We are reporting a new approach to the problem

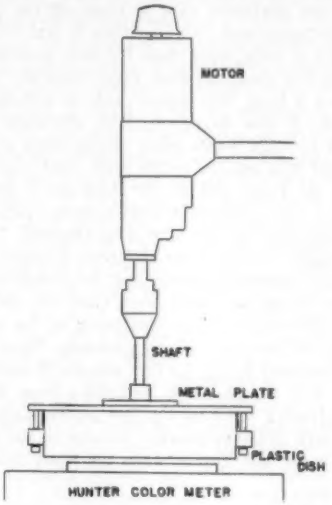

Fig. 1. Apparatus for the presentation of food samples to the Hunter Color and Color Difference Meter.

Table 1. A comparison of Hunter* "L," $+a_L$, and $+b_L$ readings taken by three methods of sample presentation.

	Sliced Marshall strawberries				Whole Canby raspberries			
	Homogenized sample	Rotated in dish	Five multiple spot readings	Average of spot readings	Homogenized sample	Rotated in dish	Five multiple spot readings	Average of spot readings
Hunter "L"	24.6	29.2	29.4 28.5 28.4 31.7 30.0	29.6	21.7	17.9	16.0 19.2 18.8 20.1 19.0	18.6
Hunter $+a_L$	27.0	31.6	32.7 32.9 28.7 32.3 30.3	31.4	30.2	27.3	26.9 26.0 28.8 28.1 28.4	27.6
Hunter $+b_L$	12.0	16.8	16.4 15.7 14.2 16.7 16.2	15.8	10.0	7.9	7.1 8.1 8.3 9.2 8.5	8.2

* L (visual lightness) and ordinates "a" and "b" are used to describe color by the Hunter system.

of securing a closer relationship between Hunter color difference measurements and Agricultural Marketing Service grades for color. It involves the use of a clear plastic dish (Fig. 1) fitted with a tight cover, the latter being coupled to a ¼-in. shaft located vertically at the center of the cover. The bottom and top of the dish are tightly connected by means of thumbscrews mounted on the outside perimeter of the sides of the dish and extending through an aluminum plate mounted to the cover of the dish. The shaft is connected to a laboratory-type variable-speed electric motor located above the meter. This motor may, in turn, be connected to the power source through a variable-speed transformer. By proper manipulations of the transformer, a speed may be selected, which reduces the oscillations of the galvanometer of the meter to a minimum and thus averages and "integrates" the color values of the product. The speed of turning of the dish is variable depending upon the nature of the product.

The entire assembly is mounted off-center to the source of light from the meter and may be either directly behind or to one side of the meter to take advantage of the area relationships of the light from the meter.

Products to be viewed by the meter are placed in the dish, the cover clamped on, and the assembly connected to the motor. To prevent scratching of the meter "viewing" plate, the assembly is raised approximately 3/16 in. above the plate. This causes no change in the readings.

Typical results by the three methods of sample presentation are shown in Table 1. This method is readily adaptable to use with other types of reflection meters.

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12 July 1954.

Improved Homogenizer for Plant Tissues

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An improved homogenizer suitable for rapid homogenization of small samples of plant tissue has been designed. This apparatus combines the advantages of the conical form used by Takahashi (*1*) and the plastic pestle described by Brendler (*2*). The conical form of pestle and mortar is advantageous because the pestle continues to fit tightly in the mortar after wear. The plastic pestle has been found to be more satisfactory than glass since the former is essentially unbreakable and very easily made in any laboratory.

The mortar is a 12-ml heavy-walled, conical centrifuge tube. This tube should be carefully selected for uniformity of taper and absence of irregularities and defects in the conical tip. If desired, a pouring lip may be added by the usual glassworking techniques.

The pestle was made by pouring about 1.8 ml of a mixture of monomeric methyl methacrylate and a catalyst into the centrifuge tube; the pestle shaft was suspended in this mixture and polymerization allowed to take place. The liquid methyl methacrylate (*3*) contained an inhibitor, 0.006 percent hydroquinone, which was removed by three extractions with approximately 0.5*N* NaOH and three extractions with distilled water The water remaining in the methyl methacrylate was removed with $CaCl_2$.

Lupereo CDB (*4*) was used to catalyze the polymerization of methacrylate. This catalyst, which is a mixture of equal parts of 2,4-dichlorobenzoyl peroxide and dibutyl phthalate, was used at a concentration of approximately 250 mg/25 ml of methyl methacrylate. To prevent the plastic from adhering to the centrifuge tube, the inside of the tube had previously been coated with a soap film and dried thoroughly. The shaft portion of the pestle was a 15-cm length of steel piano wire 3/32 in. in diameter. The portion of the shaft to be embedded in plastic was deeply notched by means of a file to provide a slip-proof union with the plastic.

The shaft was pushed through the exact center of a No. 4 tapered cork stopper. The stopper supporting the shaft was inserted in the centrifuge tube, and the shaft pushed down about ½ in. into the liquid plastic. The shaft was then centered in the plastic by carefully manipulating the cork, and the entire unit was put in an oven at 40 to 45°C and left 3 days for polymerization.

Fig. 1. Glass mortar (left) and plastic pestle with steel shaft (right).

Since there was some shrinkage during the curing process, a small amount of refitting was necessary. This was accomplished by inserting the free end of the shaft in the chuck of a heavy-duty stirring motor and holding a strip of sandpaper against the tip of the rapidly turning pestle. Slight touches of sandpaper against the other high points on the pestle soon resulted in a good fit, preferably somewhat tighter at the shoulders than at the tip. The final fitting was accomplished by pouring a suspension of carborundum powder in water into the tube, inserting the pestle, and rotating the pestle at medium speed in this mixture. The carborundum served two purposes. It completes the fitting and removes the glaze from the mortar wall. This latter step strikingly increases the efficiency of the homogenizer.

If desired, a spiral groove may be cut into the pestle from the shoulder to the tip in such a direction that the rotation of the pestle tends to carry the homogenate to the bottom of the mortar. The complete homogenizer is shown in Fig. 1.

This motor-driven homogenizer works best if sample sizes are kept to 500 mg or less. A 300-mg sample of leaf disks from the interveinal area of tobacco leaves can be completely macerated in about 30 sec. This homogenizer has been found to be very durable, and a large number of samples may be homogenized with a minimum of refitting. It is assumed that it would be equally effective for macerating animal tissues.

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19 July 1954.

New Techniques for the Study of Restoration of Compacted Soil

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About 5 years ago we (*1*) visited an airport where investigations were being made on methods of maintaining soil in a compacted condition for a firm landing strip. It appeared then that even firmly compacted soil eventually becomes restored to its normal structure. Compaction of soil that is caused by farm animals and machinery may persist for years, but it also is known to disappear in time. The effects of physical factors—wetting and drying and freezing and thawing—and the effects of bacterial and fungal growth on the soil structure have been subjected to some investigation. In contrast, the specific effects of animals in the restoration of deteriorated soil have had less attention.

These facts suggested a study of the relationships among the various physical and biological factors in the restoration and maintenance of soil structure. First we sought to devise satisfactory methods for destroying the structure of soils. In an exploratory series of experiments, surface soils from a fertile garden and from an old compost heap were mixed with water into thin mud and molded into cores in 1-pt paper cartons. These cores were removed from the cartons, air dried, and buried just below the surface near the places from which the soil was dug. In the course of a winter the cores literally disappeared as compacted objects. Wetting and drying, freezing and thawing, and extensive tunneling by earthworms and other animals all seemed to be factors in the structural restoration.

Fig. 1. Core with alfalfa meal additive, exhumed after 4 mo. Most of the original core had been removed by earthworms. Light-colored material from the core had been deposited as casts throughout the adjacent region.

In a second series of experiments, soil of lower organic content from the B horizon of Miami silt loam of a badly eroded garden, was mixed with water and molded into cylindrical cores of about 3.5 in. by 3.5 in. in diameter and in height. These core dimensions have become standard for all our experiments. The cores were buried to a depth of 3 in. in three separate sites: (i) a dense woodland, (ii) the garden from which the soil was taken, and (iii) an old field that had not been cultivated for 10 yr. After 2 yr the cores in the woodland were little changed. There was little penetration by roots and almost no evidence of shrinkage cracks or tunneling by animals. The forest appeared to have insulated the cores from the severe effects of moisture and temperature changes. In contrast, the cores buried in the two open areas showed, after 1 yr, many horizontal shrinkage cracks and some vertical ones. The cores in the old field, after 1 yr, had been pierced by the roots of grasses and weeds. There was some tunneling by wireworms. Platy structures had developed, with fungi growing on the surfaces of the plates. Nematodes, mites, and collembolans were

active in the cracks in the cores. In a few instances, ants had penetrated the larger cracks and had enlarged the spaces by nibbling at the fungi on the soil faces. The cores in the eroded garden were less affected by roots, fungi, and small animals than the cores in the old field.

As a result of these observations, a third series of cores was prepared from soil of even lower organic content, from the B_2 horizon of Crosby silt loam. One set of control cores was made by adding only water to the soil; to a second set, inorganic fertilizer and sufficient lime to bring the *p*H to neutrality were also added; to a third set, alfalfa meal was added; and to a fourth set, the insecticide, chlordane, was added. These cores were buried in late May and early June in two sites, a woodland and an open field, both of Crosby silt loam. All were buried at 1-ft intervals 5 in. beneath the surface, the types being distributed by a standard randomized formula. Half of the cores in the field were given clean surface cultivation, and the remainder were sodded over by grass that was clipped regularly.

The most rapid transformations occurred in the alfalfa-meal cores (Fig. 1) that were buried in the open field. Molds and bacteria grew quickly throughout the mass of the cores. In a few weeks the initial aggregate stability (as determined by the S.C.S. modification of the Yoder wet-sieving technique) had increased from about 20 to nearly 100 percent. There was little change in volume from wetting and drying. Earthworms ingested the material of the cores from all sides, so that within 3 mo some of them had the appearance of almost-eaten apples. Worm casts from the cores were recognizable for several inches in all directions. The nature and extent of the worm tunnels was recorded by making latex casts of the voids by a process developed earlier (*2*). Ants and microarthropods were active on the eroded surfaces of the cores.

Fig. 2. Core with no additive, exhumed after 4 mo. The shrinkage cracks and exfoliated structure are the results of alternate wetting and drying.

At the end of the first summer the remaining three types of cores in the open field showed relatively little change except for the development of horizontal shrinkage cracks with platy structure (Fig. 2). Their aggregate stability continued to be very low. Fungi developed to some extent on crack faces. Some nematodes, mites, and collembolans were found.

The cores of the various types buried in the forest soil underwent less transformation than their replicates buried in the open fields. We were surprised by the low level of faunal activity. The full implication of this phenomenon requires further study.

These experiments indicate that the restoration of compacted soil occurs in orderly processes that vary widely according to location and organic content. Cores rich in organic matter and buried in open areas develop a mass stability that retards the formation of shrinkage cracks. However, earthworms ingest large quantities of the soil and fungi, thus mixing the material of these cores with the surrounding soil. Cores low in organic matter lack this stability and develop extensive cracks into which roots may penetrate. Fungi developing on the interfaces may be eaten by microarthropods, with possible subsequent enlargement of the spaces.

Recognition of further details of the restorative process may be expected as the experiment continues. We believe that the techniques of preparing and burying standardized cores of soil, compacted by puddling and variously treated to attract or repel organisms, offer a means of studying the processes of change in soil structure through the interaction of physical and biological factors that will be useful in many aspects of soil research.

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21 May 1954.

New Design of Ultrafiltration Apparatus

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Ultrafiltration is superior to other methods for the concentration of colloidal solutions in that it (i) avoids the denaturing action of precipitating agents or heat, (ii) provides for removal of salts as well as solvent, (iii) assures essentially quantitative recoveries of the colloids, and (iv) requires little attention from the operator. A new apparatus for this purpose, similar to a filter press in design, is described in this paper. This apparatus is versatile with respect to capacity and does not require disassembly for collecting the concentrates. With its aid we have readily succeeded in obtaining up to 94-fold concentration of large vol-

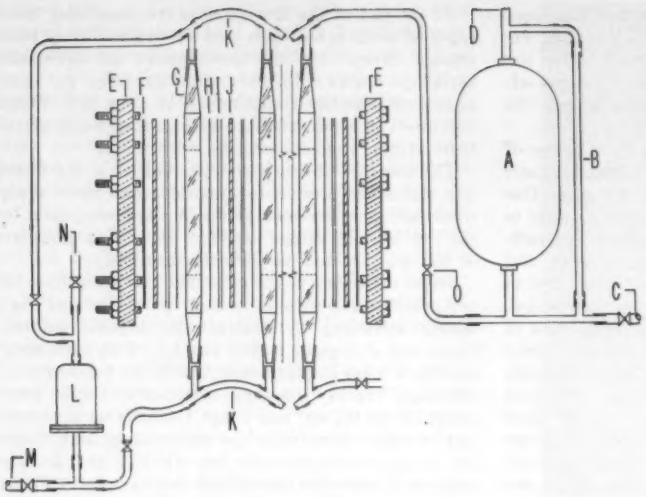

Fig. 1. Schematic diagram of assembled ultrafiltration apparatus. Filter unit is shown in exploded view: *A*, reservoir (*3*); *B*, level gauge; *C*, reservoir inlet; *D*, compressed gas inlet; *E*, end plate; *F*, rubber pad; *G*, Cell; *H*, membrane (*4*); *I*, filter paper (*5*); *J*, filter plate (*6*); *K*, manifold; *L*, receiving flask (*7*); *M*, concentrate tap; *N*, air bleeder; *O*, screw clamp.

umes of various fungal enzyme preparations. Few apparatus have previously been described for ultrafiltration on a large scale (*1, 2*).

The assembly (Fig. 1) consists principally of a reservoir *A*, a multiple filter unit *E–K*, and a receiving vessel *L*. The filter unit is made up of any desired number of cells *G* separated by semipermeable membranes *H*, double layers of filter paper *I*, and Alundum filter plates *J*, in the order shown. The cells consist of Plexiglas rings fitted with threaded Plexiglas nipples, as specified in Fig. 2. The nipples are sealed into opposite edges of the rings with Duco cement.

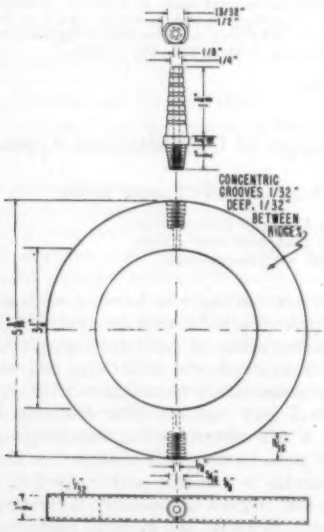

Fig. 2. Details of Plexiglas cell.

The flat surfaces of the cells are grooved as indicated to improve the seals with the semipermeable membranes. The different elements of the filter unit are clamped together by means of 12 ¼-in. bolts passing through ½-in. brass plates *E* at the ends. The openings in the cells are connected in parallel through manifolds *K* at the top and bottom. The manifolds consist of 2-mm capillary T-tubes, connected by means of cloth insert rubber tubing. Screw clamps *O* are introduced at various points in the system to facilitate filling and emptying the apparatus.

The apparatus is filled with the dilute colloid solution to be concentrated by first siphoning the solution through the lower manifold into the receiving vessel and the cells, displacing all air in these parts of the system. The bulk of the solution is then introduced through inlet *C* into the reservoir. Pressure is applied from a tank of compressed nitrogen connected to inlet *D*, forcing the water and other dialyzable materials through the membranes and filter plates. The filtrate drips from the edges of the plates into a suitable pan or trough. The contents of the cells are continuously replaced by the solution from the reservoir, which enters the cells through the upper manifold. The nondialyzable colloidal materials are held back at the surfaces of the membranes where they form concentrates of relatively high density. The concentrates flow by convection through the lower manifold into the receiving vessel. The unconcentrated solution which is displaced from the receiving vessel flows into the cells through a connection from the top of the receiver to the upper manifold. When all the dilute colloid solution has been forced out of the reservoir, the pressure is relieved, and the highly concentrated material in the receiving vessel, as well as the less concentrated contents of the cells, are finally collected through tap *M*. After use, the apparatus is cleaned by rinsing and by forcing water through the membranes and filter plates.

It is then stored at 5°C with the cells filled with water and without disassembling.

In a typical test, 17,800 ml of dilute fungal enzyme preparation were concentrated to yield 170 ml of concentrate in the receiving vessel and connecting tubes and 632 ml in the cells and manifolds. The operation, carried out at 5°C, required 5 days with an 8-cell unit. The material in the receiving vessel was found to contain 49 percent of the original enzyme, concentrated 51-fold; the material remaining in the cells contained 39 percent of the original enzyme, concentrated 11-fold. About 5 percent additional enzyme was recovered in rinsings.

The effects of volume filtered and of pressure used on the rate of filtration of distilled water and on the rate of filtration of a fungal enzyme preparation are shown by the sample data plotted in Fig. 3. The rate

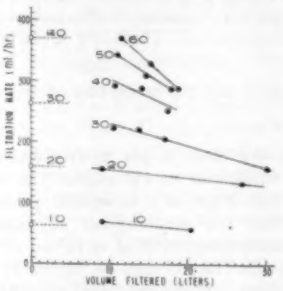

Fig. 3. Effects of volume filtered and of pressure on rate of filtration. Open circles and dotted lines represent data for distilled water; solid circles and solid lines represent data for enzyme solution. Numbers above lines represent pressures (lb/in.²). Tests were made at 5°C with an 8-cell unit.

of filtration of distilled water remained constant regardless of the volume filtered. Furthermore, an approximately linear relationship obtained between the pressure and the filtration rate. The rate of filtration of the enzymes preparation decreased, however, as the volume filtered was increased, and in this case a linear relationship was no longer maintained between the pressure and the filtration rate.

The decrease in the filtration rate of the fungal enzyme preparation was caused by the accumulation of colloidal concentrate near the membranes and by the formation of an insoluble film on the surfaces of the membranes. Partial restoration of the filtration rate was brought about when the accumulated concentrate was removed by draining the cells. Final restoration was effected by removing the insoluble film, which was accomplished by partially filling the cells with water and shaking the apparatus vigorously.

Some accumulation of colloidal material at the membranes resulting in a loss in filtration rate, appears to be unavoidable. It is probably minimal, however, in this new apparatus since the membranes are mounted vertically rather than horizontally and the convective process continuously removes most of the colloid from the neighborhood of the membranes.

References and Notes

1. F. B. Seibert, *Am. Rev. Tuberc.* **30**, 713 (1934).
2. J. J. Bullen, C. Thurlbourn, and P. Brown, *Nature* **173**, 254 (1954).
3. Stainless steel pressure tank, capacity 35 liters.
4. Schleicher and Schuell Co., Type II ultrafilter, very dense, diameter 150 mm.
5. Whatman No. 4.
6. Norton Alundum filter plate, coarse, RA 98, diameter 125 mm.
7. Seitz filter, Model L6.

6 August 1954.

Adaptable Time Switch

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In experiments with the citrus red mite (*Metatetranychus citri* McG.) it became necessary to spray water at frequent intervals on infested lemons as they revolved on a turntable. The time schedule called for 48 sprays of ½-min duration at 15-mm intervals each day. Since there was no inexpensive time switch available that would control the necessary solenoid air valve and the turntable motor with this frequency, a special time switch was constructed, which may be useful in other types of scientific work.

This device (Fig. 1) consists of a revolving paper disk *A* attached to a clock *B*. Perforations are made in the disk and so placed that silver contact points *D*, otherwise held apart by the paper, make contact at the required times. A 24-hr recording thermometer chart approximately 9½ in. in diameter is a satisfactory disk.

The switch mechanism *C* is composed of two spring brass strips *E*, approximately ¼ in. wide and 2½ in. long, each fastened at one end to an insulating wooden or plastic block *F*. To the free ends are soldered two rounded silver contact points *D*, which are held in ontact by slight tension of the brass strips. To prevent damage to the points, an electromotive force of not more than 10 v is used. This current is supplied by the transformer *G*, which is connected in series with the coil of relay *H*. This relay (*I*) is a high-capacity sen-

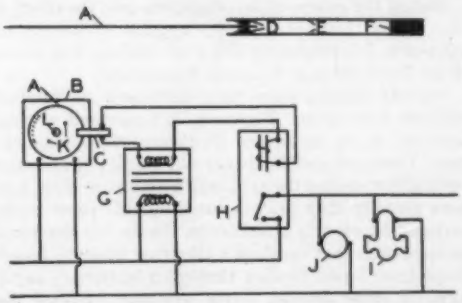

Fig. 1. Below, parts and wiring diagram of time switch. Above, enlarged sectional view of switch mechanism *C*.

sitive type that utilizes a mercury tube and controls the power circuit for the solenoid valve *I*, for the atomizer, and for the turntable motor *J*.

The clock *B* (either mechanical or electrical) is the type ordinarily used to turn on and off lights of signboards or chicken houses, and makes one revolution per day. Other rates may have to be provided for special work. On the clock selected no nonremovable parts should extend beyond the plane of the dial to interfere with the attachment of an extra dial (not shown) approximately 6 in. in diameter. This extra dial, which supports the paper disk, may be of thick Lucite or other plastic material. After the hand has been removed from the clock and a hole has been drilled in the center of the plastic dial to prevent interference with the center bolt *L*, the extra dial is fastened to the regular dial by means of two bolts *K*, which are inserted from beneath through holes of the regular dial and into tapped holes of the extra dial. These bolts are long enough to accommodate thumb nuts for fastening the perforated disk. If the controlled circuit is to be on for longer periods of time than it is off, perforations might better be provided for the off- instead of the on-time and the action of the relay reversed by turning the mercury tube end for end.

This apparatus has been in continuous operation for 10 mo, during which time it has satisfactorily controlled a solenoid valve and a small motor in accordance with prescribed schedules.

Reference

1. R. A. Fulton and F. Munger, *Science* **104**, 373 (1946).

10 May 1954.

Apparatus for Producing Drops of Uniform Size*

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Suffield Experimental Station, Ralston, Alberta, Canada

During the course of investigations into the effect of insecticides that are topically applied to insects, an apparatus for producing drops of uniform size in the range 70 to 400 μ in diameter was devised.

Various devices have been developed to produce uniform free drops. Dimmock (*1*) vibrated a glass capillary at its resonance frequency electromagnetically. Vonnegut and Neubauer (*2*) employed a similar method but excited the capillary with an air blast, and more recently they (*3*) produced monodisperse liquid particles by electric atomization. Davis (*4*) described an apparatus that employs a vibrating blade to detach drops from liquid feeding through a stationary capillary. Of these devices, Davis' apparatus offered the most promise. However, the results of attempts to adapt a model to toxicological experiments were unsatisfactory because of amplitude fluctuations in the vibrating reed. These fluctuations were apparently caused by variations in line frequency and voltage. The apparatus described here (Fig. 1) resolves this difficulty and incorporates additional improvements (*5*).

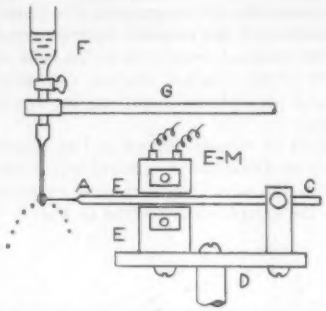

Fig. 1. Vibrator unit for production of drops of uniform size.

A coping saw blade *A* has its free end shaped to a point and sharpened at the edges. The blade tip is twisted so that it lies in a horizontal plane. Clamp *C* allows vertical and longitudinal adjustment of the blade. An electromagnet *E-M* is bolted to table *D* so that its distance from *C* may be varied. It is made up of a U-shaped, laminated iron transformer core, wound with about 4000 turns of No. 32 Formex-insulated copper wire. The liquid feed assembly *F* consists of a separatory funnel with a 27-gage hypodermic needle fitted to the tip. The assembly is held by clamp *G*, which may be positioned by micrometer adjustments.

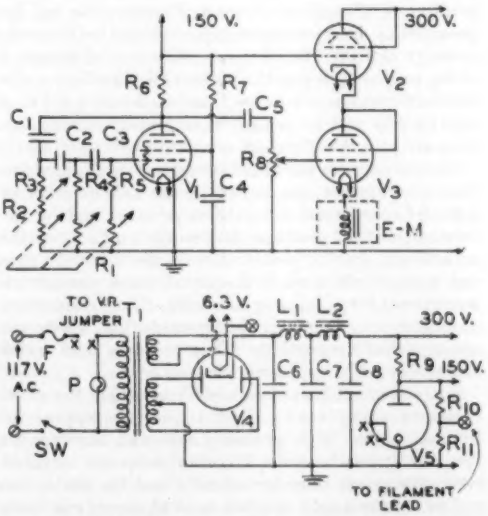

Fig. 2. Electronic circuit (*6*) for controlling vibrator.

The emf impressed across the electromagnet was made available throughout the frequency range 10 to 100 cy/sec by using a 6SJ7 tube in a phase-shift oscillator circuit (Fig. 2). An almost pure sine-wave output with good frequency stability is obtained. The amplitude is controlled by potentiometer R_3. Adjustment of R_1 gives variable frequency operation; R_2 provides fine control for locating the exact resonance frequency of the blade. The electronic circuit is fed from a constant voltage transformer and incorporates a voltage regulator stage V_2.

To operate the apparatus, the oscillator is tuned to the resonance frequency of the blade, and adjustments are made so that the vibrator tip cuts through the liquid that accumulates just above the needle tip. The amplitude of vibration is adjusted until two streams of drops are thrown off, one on each side of the needle tip. A light focused on one of the streams renders it visible. Any splash caused by liquid feeding back along the vibrating blade tip and being thrown off must be shielded out to avoid interference with the drop stream.

The size of the drops emitted depends chiefly on the rate of flow of the liquid. The frequency of the vibrator and the amplitude of the vibrating tip govern drop size to a lesser extent. To determine drop size, the frequency of generation was determined by means of a stroboscope, and the drops formed over a period of time were weighed. The mass per drop was calculated and converted to volume per drop through a density factor. Work so far has been confined mainly to oil solutions. The stains resulting from the contact of the drops with various surfaces may be made visible by dyeing the solution.

The action of the vibrator in producing drops may be seen by using a stroboscope. The blade tip emerges from the liquid, drawing a filament of the liquid after it. The filament then detaches itself from the main body of the liquid and follows in the wake of the blade, becoming spherical in shape and moving outward and downward from the needle tip.

The apparatus was developed primarily for use in insect toxicology, particularly for the topical application of drops of insecticidal solution to insects. However, it has since been found useful in other ways, for example (i) to deliver precisely measured small amounts of liquids, and (ii) as a calibration tool in insecticide spray work. Dye tracers in airplane spray experiments produce visible stain patterns on sampling surfaces. Determination of the exact relationship between stain size and drop size adds greatly to the precision of spray deposit assessments.

References and Notes

* Contribution No. 151 Forest Biology Division, Science Service, Department of Agriculture, Ottawa, Canada. Suffield Technical Paper No. 22, Defence Research Board, Department of National Defence.

1. N. A. Dimmock, *Nature* **166**, 680 (1950).
2. B. Vonnegut and R. Neubauer, General Electric Research Laboratory Occasional Rept. No. 29, Project Cirrus, Rept. No. RL-555 (1951).
3. ———, *J. Colloid Sci.* **7**, 616 (1952).
4. J. M. Davis, *U.S. Dept. Agr. Bur. Entomol. Plant Quarantine*, No. ET-295 (1951).

5. The assistance of F. E. Owen, Entomology Section, and W. L. Clink, Physics and Meteorological Section, of the Defence Research Board, Suffield Experimental Station, is gratefully acknowledged.

6. List of circuit components: C_1, C_2, C_3, 0.001 μf mica capacitor; C_4, 0.5 μf paper, 600 v; C_5, 0.1 μf paper, 600 v; C_6, C_7, 16 μf electrolytic, 450 v; C_8, 32 μf electrolytic, 450 v; *SW*-SPST switch; *F*, fuse, 1 amp; *P*, pilot lamp, 110 v; V_1, 6SJ7 tube; V_2, V_3, 6V6-GT; V_4, 6X5-GT; V_5, OD3 VR-150; L_1, filter choke, Hammond No. 152; L_2, filter choke, Hammond No. 156; R_1, frequency control, 3-gang potentiometer, 10 megohm per section; R_2, frequency control, potentiometer, 0.5 megohm; R_3, R_4, R_5, 1 megohm 0.5 w; R_6, 0.47 megohm, 0.5 w; R_7, 2.2 megohm, 0.5 w; R_8, amplitude control, potentiometer, 1 megohm; R_9, 15,000 ohm, 10 w; R_{10}, R_{11}, 68,000 ohm, 1 w; T_1, power transformer, 310-0-310 v rms, 70 ma.

13 September 1954.

Semiautomatic Device for Washing Tissues

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Department of Anatomy, College of Medicine, University of Illinois, Chicago

The semiautomatic wash rack to be described was developed (*1*) in this laboratory to facilitate the handling of tissue specimens that require prolonged washing after fixation. The apparatus stops fixation and initiates washing at any desired hour of the day.

The rack (Fig. 1) is constructed of two sheets of 14-gage stainless steel, 15½ by 5½ in. after flanging, *A* and *B*, the upper sheet *A* being perforated with 16 holes of 1⅛-in. diameter. The holes are spaced 2 in. apart from center to center lengthwise and 3¼ in. apart from center to center across. The sheets are 2½ in. apart, and they are held in position by upright pieces of stainless steel, *C* 6 by ¾ by ⅛ in., which are silver soldered at the center line of the ends of the sheets.

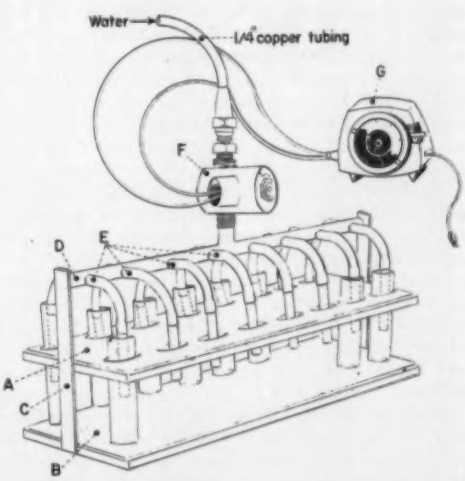

Fig. 1. Apparatus for semiautomatic wash rack.

The upright straps also serve to support a standard ¼ in. brass pipe *D* into both sides of which, at intervals of 1¾ in. center to center, a ¾-in. length of ¼-in. stainless-steel tubing *E* is silver soldered.

An electrically controlled valve *F* (*2*) is connected to the water-supply line and mounted at the center of the standard ¼-in. brass pipe. It is recommended that a vacuum breaker be installed in the water-supply line to obviate any possibility of back syphonage.

The valve is connected to a "time clock" *G* (listed in most scientific catalogs) which is set to turn the water on at the end of the desired periods of fixation and to turn the water off when washing is completed.

For fixation, properly identified tissues are placed into Moss Embedding Bags (*3*) that are inserted into vials. The water outlet for each vial is fitted with rubber tubing, and a glass spout extends from the tubing into the vial.

The design of the wash rack may readily be modified to meet the needs of individual laboratories.

Notes

1. We wish to express appreciation to Edwin Herskind, Institute of Tuberculosis Research, who constructed the apparatus to our specifications.
2. Skinner Valve No. 5-6260, 115 v, 60 cycles.
3. A. S. Aloe Co., No. 64690.

26 March 1954.

Versatile Anaerobic Spectrophotometer Cell

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This paper describes an anaerobic cell that is similar to the Thunberg tube but permits the measurement of reaction rates in the Beckman Model DU Spectrophotometer. Strict anaerobiosis is obtained by bubbling oxygen-free N_2 or helium through the cell in a manner similar to that described by Singer and Kearney (*1*). The visible absorption spectrum can be measured under anaerobic conditions during or at the end of the reaction. Provision is also made whereby one component can be reduced by catalytic hydrogenation and then added to the body of the cell under anaerobic conditions.

The apparatus (*2*) is illustrated in Fig. 1. The total height of the body should be at least 11 cm in order to prevent protein solutions from foaming into the side arm during deoxygenation. The bubbling tube is fabricated in two parts to decrease its fragility, these parts are joined by a section of voltron plastic tubing. The lower part of the bubbling tube is bent to fit in one corner of the body, out of the way of the optical path (see Fig. 1, right); it almost reaches the bottom of the body.

Anaerobic addition from the side arm. The main body, side arm, and bubbling tube (Fig. 1, left) are used. One component necessary for the initiation of the reaction is placed in the side arm either by injecting it through stopcock *A* by means of a hypodermic

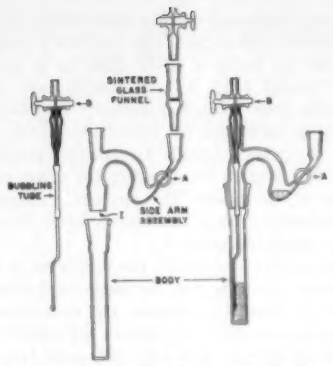

Fig. 1. Component parts of anaerobic Beckman cell.

needle or by inverting the side-arm assembly and carefully pipetting it through opening *I*. The other components are placed in the body. The joints are lubricated and the apparatus is assembled as shown in Fig. 1, right. Oxygen-free nitrogen or helium, prepared by passing the gas through heated copper screens, is bubbled through the cell. After 10 min, stopcock *A*, and then stopcock *B*, are closed, and the cell is transferred to the spectrophotometer.

Owing to the height of the assembly, it is necessary to build a light-tight box that fits over the spectrophotometer cell compartment mounting block, carriage, and phototube compartment. After a zero reading is taken, the contents of the side arm are tipped into the body and the reaction is started. Readings are taken in the usual way. It is possible to run two anaerobic cells simultaneously by placing them in positions 1

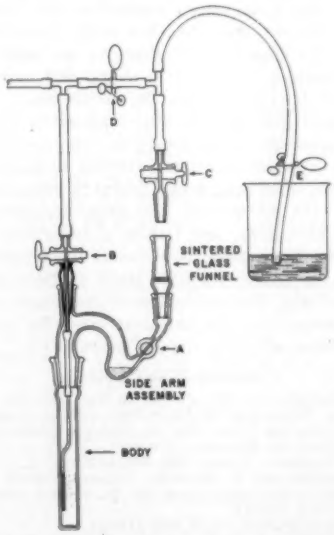

Fig. 2. Anaerobic Beckman cell assembled.

and 3 of the cuvette holder. Standard cuvettes containing appropriate blanks can be placed in positions 2 and 4.

Catalytic hydrogenation. The sintered glass funnel is used in the side-arm assembly, and the manifold is connected to the anaerobic cell as illustrated in Fig. 2. With all pinchclamps and stopcocks open, the manifold system is flushed for a few minutes. Stopcock *A* is then closed while the nitrogen continues to flow through stopcock *C* and tube *E*. The catalyst (platinum black, palladium black, and so forth) and the solution to be reduced (0.2 ml maximum) are then placed on the sintered disk, and stopcock *C* is inserted into the upper joint of the sintered glass funnel. Pinchclamp *D* is closed and stopcock *A* is immediately opened, thus shunting the flow of nitrogen through the cell, up through the sintered glass funnel, and out tube *E*. When reduction is complete, stopcock *B* is closed, pinchclamp *D* is opened, and the pinchclamp on tube *E* is closed, in that order. The pressure builds up and forces the solution through the sintered glass plate, through stopcock *A*, and into the side arm (*3*). When all the solution has been filtered, pinchclamp *E* is opened, stopcock *A* is closed, and the sintered glass funnel is removed. The subsequent steps are carried out as previously described.

This apparatus has been used successfully to study the enzymatic reduction of cytochrome oxidase. Since this enzyme is readily reoxidized by small amounts of oxygen (*4*), and since no difficulties were encountered in maintaining this enzyme in its reduced state, adequate anaerobic conditions are provided by this assembly.

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* Present address, Department of Anatomy, University of Minnesota Medical School, Minneapolis.

1. T. P. Singer and E. Kearney, *J. Biol. Chem.* **183**, 409 (1950).
2. Obtainable from A. F. Bittel, 368 E. 123 St., Cleveland 8, Ohio.
3. On forcing the solution through the sintered plate, a positive pressure of 8 mm-Hg is built up in the anaerobic cell.
4. E. G. Ball, C. F. Strittmatter, and O. Cooper, *J. Biol. Chem.* **193**, 635 (1951).

18 August 1954.

New Electrophoresis Cell for Dual Analysis

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Jewish Chronic Disease Hospital, Brooklyn, New York

Most of the cells in use today for moving-boundary electrophoresis are based on the design and principles of Tiselius (*1*). These cells are of two types. One, following Tiselius' original design, consists of a sliding sectional U-tube and detachable electrode vessels. The other type, which has come into use in recent years, is a one-piece cell. The essential feature of both cells is that the U-tube has vertical limbs of rectangular cross section with optically flat faces and electrode vessels attached to both of its sides. In the one-piece cell there are no sliding sections, and the boundaries are formed by careful layering rather than by shearing.

One disadvantage of moving-boundary electrophoresis is that, with the cells currently available, only one experiment at a time can be performed. Since from 1 to 3 hr is required for an experiment, the usefulness of the method is limited by the amount of time required per run. To overcome this difficulty, many investigators have resorted to paper electrophoresis, which has sufficient capacity for multiple simultaneous runs. However, this method is not always a satisfactory substitute, because its resolution of components is often inferior to that obtained with the moving-boundary technique, and the determination of mobilities is subject to various correction factors (*2*).

Electrophoretic cells capable of multiple analysis have been developed by Polson (*3*). These employ the center section of a sliding sectional cell and a semipermeable membrane across the bottom of the channels. Apparently only descending patterns can be obtained with these cells.

In the course of a project performed at this laboratory it was found necessary to do pairs of electrophoretic analyses under as nearly identical conditions as possible. To satisfy these conditions, we have developed the dual analysis cell described here. Because of the relative ease of filling and handling, the one-piece

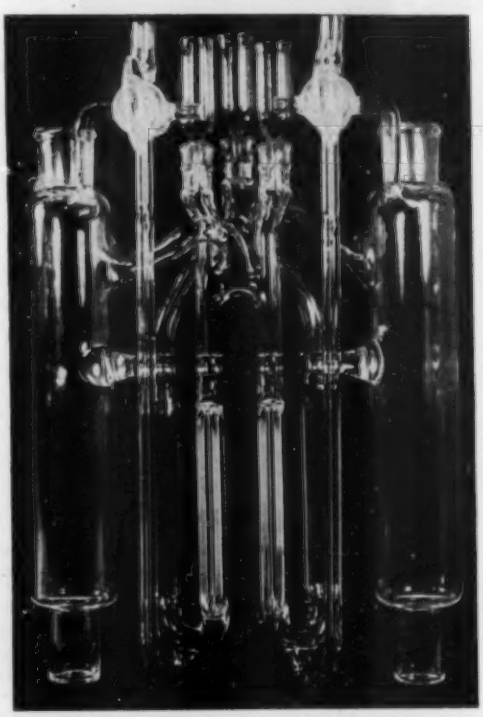

Fig. 1. The dual electrophoresis cell.

design, which is quite satisfactory for most purposes, was chosen. Furthermore, the design permits one to obtain ascending or descending patterns as desired.

The dual analysis electrophoresis cell consists of two U-tubes so connected as to constitute a parallel electric circuit whose branches are of equal path length (Fig. 1). The two inner limbs are of rectangular cross section and constitute the optical sections of the cell. The outer limbs, made of nonoptical glass tubing, function as reservoirs for the solutions to be analyzed. In principle all four channels could be of rectangular cross section and function optically, provided that the Schleiren lens of the optical system is of a sufficiently large diameter. In this case, both ascending and descending patterns could be obtained for each sample. This particular cell was designed to fit the Aminco-Stern portable electrophoresis apparatus. The lens diameter in this instrument dictated the use of only two optical channels. Depending on the position of the starting boundaries and the polarity of the electrodes, one may therefore obtain either ascending or descending patterns, but not both. In order to allow the dual analysis of two different samples, a separate filling capillary is connected to the base of each U-tube. Boundary formation is effected by the simultaneous filling of the channels through the capillaries at a slow uniform rate of flow.

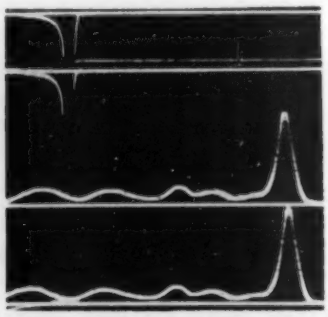

Fig. 2. Patterns obtained on dual analysis of normal human serum. Reading from top to bottom: starting boundary, left channel; starting boundary, right channel; final pattern, left channel; final pattern, right channel.

To test the identity of the patterns obtained from the two channels, a sample of normal serum dialyzed against barbiturate buffer (pH 8.6; ionic strength 0.1) was divided into two aliquots and analyzed simultaneously in the cell. The patterns obtained are shown in Fig. 2. The relative percentages of each component are shown in Table 1. As can be seen, the patterns are virtually identical, both in shape and position of the components. The values of the relative percentages of the components are quite similar. Such differences as do occur may be ascribed to errors associated with the procedure used in the tracing and planimetry of the patterns.

Table 1. Relative percentage concentration of serum protein components analyzed simultaneously.

Channel	Components				
	Albumin	Alpha-1	Alpha-2	Beta	Gamma
Left	52.1	4.4	10.2	14.3	19.0
Right	51.7	4.5	10.2	14.5	19.1

Aside from dual runs on the same sample, the cell has been found to be extremely useful for analyzing two different samples under the same conditions. For statistical and comparative purposes its advantages are evident. For routine analyses the double output of the cell is a saving of both time and labor (*4*).

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1. A. Tiselius, *Trans. Faraday Soc.* **33**, 524 (1937).
2. H. J. McDonald *et al.*, *Clinical Chemist* **5**, 35 (1953).
3. A. Polson, *Nature* **168**, 996 (1951); *ibid.* **170**, 628 (1952).

4. We wish to acknowledge our gratitude to Karl Schuman of Cliffside Park, N.J., who constructed the original model of the cell, and to A. Henley of the American Instrument Co., Silver Springs, Md., for his activity in the further development of the cell. We are indebted to B. W. Volk, director of laboratories and A. Saifer, chief of the Biochemistry Department, Jewish Chronic Disease Hospital, for their encouragement and aid in permitting this work to be performed under grant No. B-285 of the U.S. Public Health Service.

30 July 1954.

Nowadays it is a truism that advances in physical science depend upon advances in the instruments which scientists employ.—KARL DARROW.

Communications

Simple Manual Pipette for Toxic Reagents

Because of the many varied chemical reagent solutions in use in our laboratory for biochemical analyses, the need arose for a safe method of pipetting toxic solutions to avoid getting any dangerous or toxic solutions in the operator's mouth, either by carelessness, by fumes, by overpipetting, or by air traps.

A simple automatic pipette was therefore devised and constructed to handle small volumes of toxic reagents (*1*). It has been used in this laboratory to pipette silver nitrate reagent, sodium hydroxide solutions, concentrated ammoniacal solutions, sodium cyanide reagent, sulfuric, nitric, and trichloracetic acid solutions, phenol reagent, and molybdate-sulfuric acid reagent.

The component parts are a standard bottle with a standard taper mouth, a standard taper ground joint, and a standard pipette, of Pyrex glass, with the ring seal and the side-arm tube fabricated by hand (*2*). The complete assembly is interchangeable so that a 1-liter bottle pipette can be cleaned and used in another 1-liter bottle. We have used both 5- and 10-ml pipettes and 500- and 1000-ml bottles for various reagent solutions, and they have exhibited excellent strength in usage.

The automatic pipette reagent bottle (Fig. 1) consists of a 1000-ml Pyrex reagent bottle *A* with S.T. opening fitted with a 29/42 S.T. Pyrex ground joint *D*. The ring seal *C* is made by sealing a 5- or 10-ml red-line Pyrex measuring pipette *B* to the S.T. ground joint well above the top graduation of the pipette so that the accuracy of the pipette is not altered. The rubber pressure bulb *G* is fitted to an 8-mm tube that is sealed to the ground joint *H*. The thumb safety air-pressure release *F* is a small 8-mm opening, slightly flared and fire-polished. The S.T. joint fitting *E* for the bottle is lubricated with silicone stopcock grease (*3*) to facilitate both ease of removal of the entire assembly and a clear view of the graduations when making measurements. A small washer *J* of tygon tubing is fitted below the top of the pipette, and when not in use, a Pyrex Wasserman tube *K*, cut in half and packed with glass wool in the sealed end, acts as a closure for the mouth of the pipette to minimize contamination or evaporation of the reagent or solution in the bottle. In use, manual pressure is exerted on the rubber bulb, with the thumb sealing the safety opening *F*, forcing the solution in the bottle up into the pipette. When the solution is above the zero mark but below the mouth of the pipette, the safety opening is released, allowing equalization of air pressure, and the forefinger is immediately applied to the opening of the pipette. The pipette assembly is then removed from the bottle and the excess solution allowed to run back to the zero mark. The solution in the pipette, with the forefinger as control, is then dispensed as usual in any amount up to 10 ml.

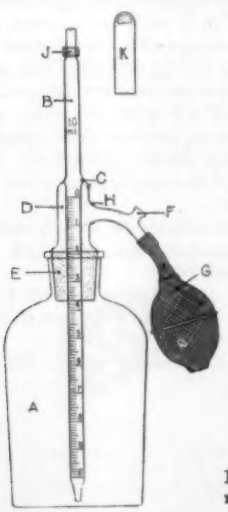

Fig. 1. Pipette for toxic reagents.

The actual filling and zero adjustment of a 10-ml sample of solution in this apparatus takes less than 15 sec and it has proved satisfactory to the personnel who have been using it. More than six of these assemblies have been in constant daily use for a 4-mo period without breakage or freezing of the closure.

HARRY EISENBERG

Department of Medicine,
The Johns Hopkins University
School of Medicine and Hospital

Notes

1. This pipette has been found useful during technical procedures carried out in The Johns Hopkins Hospital on a project supported by a contract between the U.S. Atomic Energy Commission and The Johns Hopkins University with Dr. John Eager Howard as Research Contract Director.
2. Made to specifications by T. Elmo Maiolatesi, Baltimore, Md.
3. Dow-Corning Silicone Stopcock Grease, which has proved impervious to most of the reagents we have used with the pipette assembly.

30 July 1954.

Constant Current or Constant Voltage?

It is sometimes stated that for paper electrophoresis one needs *constant current* not *constant voltage*. The very active development of paper electrophoresis now going on makes it desirable to consider the basis of this statement. The following analysis shows that it is sometimes true and sometimes not.

The *desideratum* in electrophoresis is a known, constant, and reproducible electric field for which the field strength E can be measured in volts per centimeter.

The direct calculation of E involves dividing the voltage difference between the ends of the migration path by the path length. In the usual type of free-solution electrophoresis cell, the direct measurement of voltages in the migration path is inconvenient and one may then resort to an indirect method based on the equation $E = I/KA$, which assumes that the conductivity K is constant and the cross-sectional area A is uniform. With these conditions satisfied, a constant-current supply insures the required electric field.

The situation is not the same in paper electrophoresis. Here we must distinguish between (i) apparatus in which the paper is exposed to an atmosphere and (ii) apparatus in which it is pressed between two solid surfaces.

When the paper is exposed to an atmosphere, whether saturated or not, evaporation from the paper occurs because of heat generated by the electric current. The quantity of heat H is calculated for a constant-current supply from the equation H (cal/min) = 14.3 RI^2, and for a constant voltage supply from the equation H (cal/min) = 14.3 V^2/R. Calculations based on a paper strip carrying 7 ma at 500 v indicate that as much as 0.1 ml of water may be evaporated per minute. A sequence of events is thereby initiated (concentration of buffer, influx of water from electrode compartments, and decreased resistance), which, with a constant-voltage supply, results in increased current density, increased heat production, and still more evaporation. At higher voltages, the cycle may proceed to the point of igniting the paper. This occurred in one case while operating at room temperature with 1000 v across a 30-cm strip of paper using 0.1M barbital buffer.

On the other hand, a constant-current supply, while it does not prevent the change in conductivity, does control the heat production, but at the cost of a constantly decreasing applied voltage as the resistance decreases. In this case, therefore, a choice must be made between constant-voltage supply with the danger of overheating and constant-current supply with the disadvantage of varying migration rate.

When the paper is compressed between two solid surfaces—for example, glass plates—evaporation is completely prevented and the temperature rise is controlled by the temperature of the contact surfaces. If no other disturbing factors are present, either constant-current or constant-voltage supply can be used. However, it is found experimentally that even with constant pressure the conductance of the paper-buffer system increases during the run, although not as much as in the exposed strip, apparently because of electroosmotic influx of buffer. The constant-voltage supply is therefore preferred, since it has the advantage of producing constant field strength. The field strength is calculated by dividing applied voltage by paper length (measured between buffer surfaces).

The subject is treated more fully by the writer in a forthcoming monograph, "Paper and zone electrophoresis manual" (E-C Apparatus Co., New York, 1954).

SAMUEL RAYMOND

College of Physicians and Surgeons, Columbia University, New York 32

13 September 1954.

Glass-Fiber Paper Impregnated with Silicic Acid as a New Chromatographic Tool

In attempting to separate saturated mono-, di-, and triglycerides by paper chromatography, it was found difficult to locate the spots, because the paper is destroyed by the drastic tests necessary to locate these compounds. To overcome this difficulty, a fine glass-fiber filter paper was obtained, which, when impregnated with silicic acid, was found to have chromatographic properties similar to that of silicic acid columns.

D. L. Fillerup and J. F. Mead [*Proc. Soc. Exptl. Biol. Med.* **83**, 574 (1953)] were able to separate a mixture of triglycerides, fatty acids, cholesterol, and cholesterol esters on a silicic acid column by using increasing amounts of ethyl ether in petroleum ether as eluting solvents. It was found in this laboratory that mono-, di-, and tripalmitin, cholesterol, and cholesterol acetate can be separated on glass paper impregnated with silicic acid using a developing solvent consisting of a 2-percent ethyl ether in isooctane. Typical R_f values obtained were as follows: 1-monopalmitin, 0.05; dipalmitin, 0.27; cholesterol, 0.41; tripalmitin, 0.79; cholesterol acetate, 1.0.

The location of the sterol spots was accomplished by spraying one side of the chromatogram with the Liebermann-Burchard reagent followed by heating over an electric pot plate with exposed heating element. Cholesterol and cholesterol acetate appeared as bright pinkish-red spots on a white background. All areas containing carbon compounds were located by spraying the reverse side of the chromatogram with a dichromate-sulfuric acid-water solution followed by heating over the hot plate. All areas containing carbon compounds appeared as light to dark grayish-black spots on a yellowish-orange background. The color of the spot depended in large measure upon the amount of carbon present.

This technique is being adapted to the separation of other groups of compounds. The details of the procedure will be published later.

JULIUS W. DIECKERT
RAYMOND REISER

Department of Biochemistry and Nutrition, Texas Agricultural and Mechanical College, College Station

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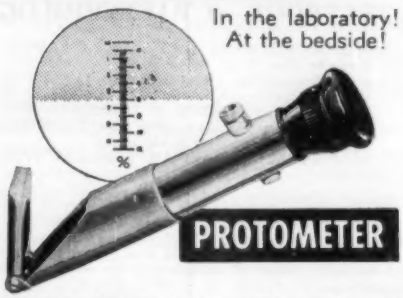

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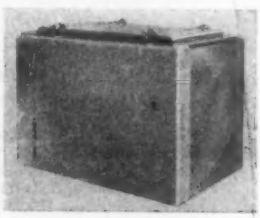

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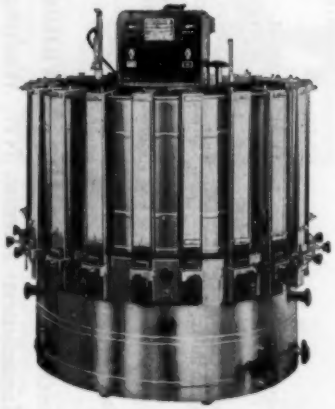

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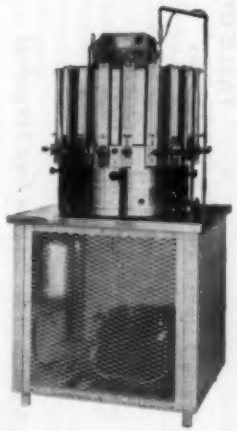

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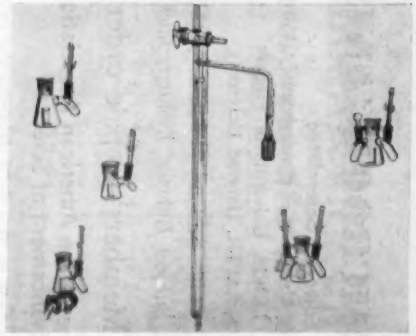

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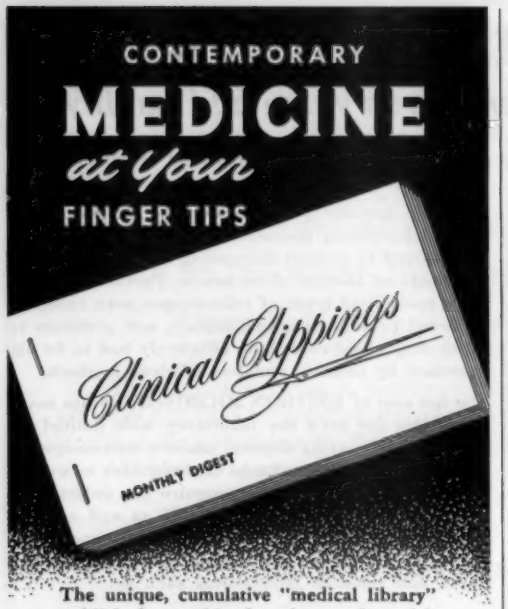

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Meetings & Conferences

November

18–19. National Assoc. of Corrosion Engineers, western region, Los Angeles, Calif. (J. G. Kerr, C. F. Braun & Co., 1000 S. Fremont Ave., Alhambra, Calif.)

18–19. Soc. of Exploration Geophysicists, 8th annual midwestern, Dallas, Tex. (R. C. Dunlap, 624 S. Cheyenne, Tulsa, Okla.)

18–20. Acoustical Soc. of America, semiannual, Austin, Tex. (W. Waterfall, 57 E. 55 St., New York 22.)

18–20. Symposium on Precision Electrical Measurements, Teddington, Eng. (Director, National Physical Laboratory, Teddington, Middlesex, Eng.)

19–20. Operations Research Soc. of America, Washington, D.C. (D. A. Katcher, 7100 Connecticut Ave., Chevy Chase 15, Md.)

19–30. International Cong. of Civil Engineers, 2nd, Caracas, Venezuela. (L. B. Diaz, Av. Principal de los Caobos, Apartado 2006, Caracas.)

25–26. Inst. of Metals, London, England. (S. C. Guillan 4, Grosvenor Gardens, London, S.W. 1.)

26–27. American Physical Soc., Chicago, Ill. (K. K. Darrow, Columbia Univ., New York 27.)

26–27. American Soc. of Animal Production, Chicago, Ill. (W. M. Beeson, Dept. of Animal Husbandry, Purdue Univ., Lafayette, Ind.)

26–27. Tennessee Acad. of Science, Nashville, Tenn. (I. H. Tipton, Physics Dept., Univ. of Tennessee, Knoxville.)

28–1. American Soc. of Refrigerating Engineers, Philadelphia, Pa. (J. I. Szabo, 40 W. 40 St., New York 18.)

28–3. American Soc. of Mechanical Engineers, annual, New York City. (O. B. Schier, II, 29 W. 39 St., New York 18.)

29–1. Assoc. of Military Surgeons, Washington, D.C. (R. R. Sayers, Armed Forces Inst. of Pathology, Washington 25.)

29–2. American Medical Assoc., clinical, Miami, Fla. (G. F. Lull, 535 Dearborn St., Chicago 10, Ill.)

30–2. Electronic Computer Clinic, 1st, New York, N.Y. (R. Rimbach, 845 Ridge Ave., Pittsburgh 12, Pa.)

December

1–2. Animal Care Panel, Chicago, Ill. (R. J. Flynn, Box 299, Lemont, Ill.)

1–3. American Rocket Soc., New York, N.Y. (ARS, 33 W. 39 St., New York 18.)

1–7. International Cong. on Medicinal and Similar Plants, São Paulo, Brazil. (P. Artigas, Rua Tres Rios 363, São Paulo.)

1–3. Pan American Pharmaceutical and Biochemical Cong., 3rd, São Paulo, Brazil. (C. Fontoura, Rua Caetano Pinto 129, São Paulo.)

3–4. Oklahoma Acad. of Science, Tulsa, Okla. (R. E. Olson, Dept. of Geography, Univ. of Oklahoma, Norman.)

3–5. American Psychoanalytic Assoc., New York, N.Y. (H. L. Frank, 745 5 Ave., New York 22.)

4. American Alpine Club, Philadelphia, Pa. (J. C. Oberlin, 909 Leader Bldg., Cleveland 14, Ohio.)

5. American Acad. of Dental Medicine, 9th mid-annual, New York, N.Y. (W. M. Greenhut, 124 E. 84 St., New York 28.)

5–8. American Soc. of Agricultural Engineers, winter, Chicago, Ill. (F. B. Lanham, ASAE, St. Joseph, Mich.)

Meetings & Conferences

December, ***contd.***

5–10. Radiological Soc. of North America, annual, New York, N.Y. (D. S. Childs, 713 E. Genesee St., Syracuse 2, N.Y.)

6–9. Entomological Soc. of America, Houston, Tex. (A. B. Gurney, 1530 P St., NW, Washington 5.)

8–10. Eastern Joint Computer Conf., 4th annual, Philadelphia, Pa. (EJCC, P.O. Box 7825, Philadelphia 1.)

9–11. Texas Acad. of Science, annual, San Antonio, Tex. (G. H. Baird, P.O. Box 228, Huntsville.)

10–12. Florida Acad. of Science, Tallahassee, Fla. (R. A. Edwards, Dept. of Geology, Univ. of Florida, Gainesville.)

11–14. American Acad. of Optometry, annual, Toronto, Canada. (C. C. Koch, 1502 Foshay Tower, Minneapolis 2.)

11–22. World Forestry Cong., 4th, Dehra Dun, India. (T. Street, Foreign Agricultural Service, U.S. Department of Agriculture, Washington 25.)

12–15. American Inst. of Chemical Engineers, annual, New York, N.Y. (AIChE, 120 E. 41 St., New York 17.)

26–28. American Statistical Assoc., Berkeley, Calif. (S. Weiss, 1108 16 St., NW, Washington 6.)

26–29. National Science Teachers Assoc., Berkeley, Calif. (R. H. Carleton, 1201 16 St., NW, Washington 6.)

26–30. Inst. of Mathematical Statistics, Berkeley, Calif. (K. J. Arnold, Dept. of Mathematics, Michigan State College, E. Lansing.)

26–31. American Association for the Advancement of Science, annual, Berkeley, Calif. (R. L. Taylor, 1515 Massachusetts Ave., NW, Washington 5.)

26–31. American Nature Study Soc., Berkeley, Calif. (H. B. Ross, State Teachers College, Fitchburg, Mass.)

27. Metric Assoc., Washington, D.C. (V. G. Shinkle, 1916 Eye St., NW, Washington 6.)

27–28. American Folklore Soc., New York, N.Y. (M. Leach, Bennett Hall, Univ. of Pennsylvania, Philadelphia 4.)

27–28. Ecological Soc. of America, Berkeley, Calif. (J. F. Reed, Dept. of Botany, Univ. of Wyoming, Laramie.)

27–29. American Mathematical Soc., annual, Pittsburgh, Pa. (E. G. Begle, AMS, Yale University, New Haven, Conn.)

27–29. Arctic Inst. of North America, Berkeley, Calif. (R. C. Wallace, 4 Centre St., Kingston, Ont., Canada.)

27–29. Astronomical Soc. of the Pacific, Berkeley, Calif. (S. Einarsson, Leuschner Observatory, Univ. of California, Berkeley 4.)

27–29. International Conf. on Animal Venoms, Berkeley, Calif. (N. Porges, Eastern Regional Research Laboratory at Wyndmoor, Philadelphia, Pa.)

27–29. Western Soc. of Naturalists, Berkeley, Calif. (J. L. Mohr, Univ. of Southern California, Los Angeles 7.)

27–30. Berkeley Symposium on Mathematical Statistics and Probability, 3rd, Berkeley, Calif. (J. Neyman, Dept. of Mathematics, Univ. of California, Berkeley 4.)

27–30. Econometric Soc., Detroit, Mich. (R. L. Cardwell, Cowles Commission, Univ. of Chicago, Chicago 37.)

27–30. National Assoc. of Biology Teachers, Berkeley, Calif. (P. Webster, Bryan City High School, Bryan, Ohio.)

27–30. Soc. of Systematic Zoology, Berkeley, Calif. (R. E. Blackwelder, U.S. National Museum, Washington 25.)

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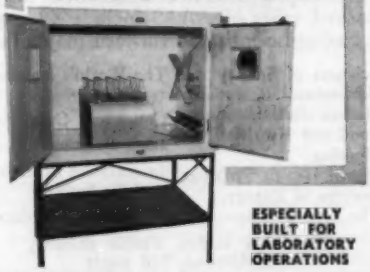

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Meetings & Conferences

December, *contd.*

28–29. Linguistic Soc. of America, Detroit, Mich. (A. A. Hill, 1719 Massachusetts Ave., NW, Washington 6.)

28–29. Meteoritical Soc., Berkeley, Calif. (J. A. Russell, Univ. of Southern California, Los Angeles 7.)

28–29. Northwest Scientific Assoc., Missoula, Mont. (F. J. Schadegg, Eastern Washington College of Education, Cheney, Wash.)

28–30. American Economic Assoc., Detroit, Mich. (J. W. Bell, Dept. of Economics, Northwestern Univ., Evanston, Ill.)

28–30. American Meteorological Soc., Berkeley, Calif. (K. C. Spengler, 3 Joy St., Boston 8, Mass.)

28–30. American Physical Soc., Berkeley, Calif. (J. Kaplan, Dept. of Physics, Univ. of California, Los Angeles 24.)

28–30. American Soc. of Limnology and Oceanography, Berkeley, Calif. (B. H. K. Ketchum, Woods Hole Oceanographic Institution, Woods Hole, Mass.)

28–30. American Soc. of Zoologists, Chapel Hill, N.C. (R. T. Kempton, Vassar College, Poughkeepsie, N.Y.)

28–30. Archaeological Inst. of America, annual, Boston, Mass. (C. G. Yavis, Andover Hall, Francis Ave., Cambridge 38, Mass.)

28–30. Gerontological Soc., annual, Gainesville, Fla. (N. W. Shock, Baltimore City Hospitals, Baltimore 24, Md.)

29. Assoc. for Symbolic Logic, Pittsburgh, Pa. (J. Barlaz, Rutgers Univ., New Brunswick, N.J.)

29–30. History of Science Soc., New York, N.Y. (M. Boas, Brandeis Univ., Waltham, Mass.)

30. Mathematical Assoc. of America, Pittsburgh, Pa. (H. M. Gehman, Univ. of Buffalo, Buffalo 14, N.Y.)

30. Soc. of General Physiologists, Berkeley, Calif. (J. B. Buck, National Institutes of Health, Bethesda 14, Md.)

January

2–8. Indian Science Congress Assoc., 42nd, Baroda, (ISCA, 1 Park St., Calcutta 16.)

11–14. American College of Surgeons, Inter-American session, Lima, Peru. (M. L. Mason, 40 E. Erie St., Chicago 11, Ill.)

12–15. World Symposium on Applied Solar Energy, Phoenix, Ariz. (M. L. Kastens, Stanford Research Inst., Stanford, Calif.)

13. American Genetic Assoc., annual business, Washington, D.C. (R. M. Cook, AGA, 1507 M St., NW, Washington.)

20–22. American Physical Soc., New York, N.Y. (K. K. Darrow, Columbia University, New York 27.)

21. Public Health Workshop on Dental Programs in Industry, 3rd, New York, N.Y. (A. J. Asgis, Hotel Statler, New York.)

24–27. American Soc. of Heating and Ventilating Engineers, Philadelphia, Pa. (A. V. Hutchinson, 62 Worth St., New York 13.)

26–2. Australian and New Zealand Assoc. for the Advancement of Science, Melbourne, Australia. (J. R. A. McMillan, 157 Gloucester St., Sydney.)

27. American Federation for Clinical Research, western section, Carmel, Calif. (A. B. French, College of Medicine, Univ. of Utah, Salt Lake City.)

February

7–9. Conf. on Silicosis and Occupational Chest Diseases, Saranac Lake, N.Y. (N. R. Sturgis, Jr., Saranac Laboratory, Saranac Lake.)

Meetings & Conferences

February, *contd.*

7–11. American Soc. of Civil Engineers, San Diego, Calif. (W. N. Carey, 33 W. 39 St., New York 18.)

11–25. Pan American Acad. of General Practice, Lima, Peru. (A. Martinez, 54 E. 72 St., New York 21.)

13–17. American Inst. of Mining and Metallurgical Engineers, annual, Chicago, Ill. (E. H. Robie, 29 W. 39 St., New York 18.)

14–19. Latin American Cong. of Physical Medicine, Lima, Peru. (C. L. de Victoria, 176 E. 71 St., New York 21.)

17–19. American Acad. of Forensic Sciences, Los Angeles, Calif. (W. J. R. Camp, 1853 Polk St., Chicago 12, Ill.)

28–2. American Educational Research Assoc., St. Louis, Mo. (F. W. Hubbard, 1201 16 St., NW, Washington 6, D.C.)

March

2–4. American Assoc. of University Professors, Gatlinburg, Tenn. (R. E. Himstead, AAUP, 1785 Massachusetts Ave., NW, Washington 6, D.C.)

7–11. American Soc. of Photogrammetry, Washington, D.C. (C. E. Palmer, 1000 11 St., NW, Washington 1.)

7–11. National Assoc. of Corrosion Engineers, 11th annual, Chicago, Ill. (A. B. Campbell, 1061 M & M Bldg., Houston 2, Tex.

14. American Educational Research Assoc., Denver, Colo. (F. W. Hubbard, 1201 16 St., NW, Washington 6, D.C.)

14. Wildlife Soc., Montreal, Canada. (D. L. Leedy, Fish and Wildlife Service, Washington 25, D.C.)

17–19. American Physical Soc., Baltimore, Md. (K. K. Darrow, Columbia University, New York 27).

17–19. National Wildlife Federation, Montreal, Canada. (C. H. Callison, 232 Carroll St., NW, Washington 12, D.C.)

17–2. Inter-American Statistical Conf., 3rd, Santiago, Chile. (IASI, Pan American Union, Washington 6, D.C.)

20–25. American Assoc. of Dental Schools, annual, Chicago, Ill. (M. W. McCrea, 42 S. Greene St., Baltimore 1, Md.)

24–26. National Science Teachers Assoc., Cincinnati, Ohio. (R. H. Carleton, 1201 16 St., NW, Washington, D.C.)

28–31. American Assoc. of Petroleum Geologists, New York, N.Y. (E. H. Powers, Box 670, Fort Worth, Tex.)

28–1. Western Metal Exposition, 9th, Los Angeles, Calif. (W. H. Eisenman, 7301 Euclid Ave., Cleveland 3, Ohio.)

31–2. Soc. of Research in Child Development, Monticello, Ill. (C. B. Stendler, College of Education, Univ. of Illinois, Urbana.)

April

1–5. Japan Medical Cong., Kyoto. (M. Goto, Univ. Hospital, Kyoto Univ., Kyoto.)

2. Kappa Delta Pi, Cleveland, Ohio. (E. I. F. Williams, 238 E. Perry St., Tiffin, Ohio.)

3–6. American Astronomical Soc., Princeton, N.J. (C. M. Huffer, Washburn Observatory, Madison 6, Wis.)

3–7. American College Personnel Assoc., Chicago, Ill. (C. Evans, Univ. of Indiana, Bloomington.)

4. American Educational Research Assoc., Cleveland, Ohio. (F. W. Hubbard, 1201 16 St., NW, Washington, 6, D.C.)

5–7. Kansas Acad. of Science, Lawrence. (C. T. Rogerson, Dept. of Botany, Kansas State College, Manhattan.)

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Isotopic Gas Analysis for Biochemists

By R. F. Glascock

Oct. 1954, 247 pp., illus., $5.80

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Edited by R. J. C. Harris
Institute of Cancer Research, London

1954, 415 pp., illus., $10.00

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5. Details of the Gymnasium for Men—center of the Meeting—and campus.
6. Titles of the latest foreign and domestic scientific films to be shown in the AAAS Science Theatre.
7. Exhibitors in the 1954 Annual Exposition of Science and Industry and descriptions of their exhibits.

Directory content

1. AAAS officers, staff, committees for 1954.
2. Complete roll of AAAS presidents and their fields.
3. The 260 affiliated organizations.
4. Historical sketch and organization of the Association; the Constitution and Bylaws.
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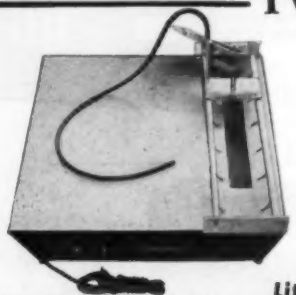

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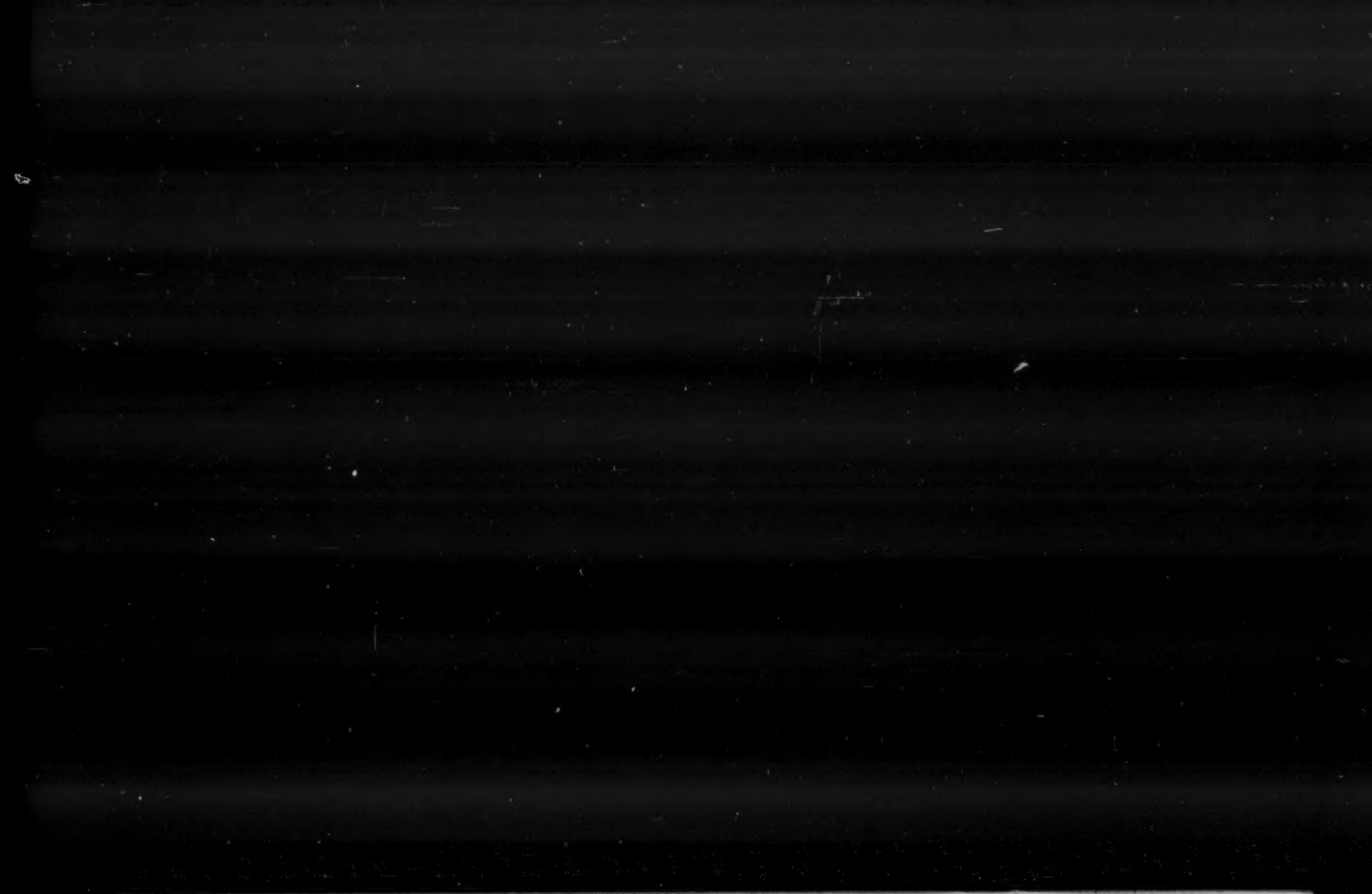
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